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PHILOSOPHICAL TRANSACTIONS.

I. *An Experimental Determination of the Velocity of Sound.*

By E. J. STONE, *F.R.S., Astronomer Royal at the Cape of Good Hope.*

Received August 21,—Read November 23, 1871.

A GALVANIC current passes from the batteries at the Royal Observatory, Cape of Good Hope, at 1 o'clock, Cape mean time. This current discharges a gun at the Castle, and through relays drops a time-ball at Port Elizabeth.

It appeared to me that a valuable determination of the velocity of sound might be obtained by measuring upon the chronograph of the Observatory the time between the sound reaching some point near the gun and that of its arrival at the Observatory. I thought also that it would be a point of interest to check, within the limits of our changes of temperature, the variations in the velocity of sound as dependent upon temperature, and to obtain some test of the applicability of the coefficient of expansion of dry air, as determined in cabinet experiments, to the mixture of air and water which would be the medium of the propagation of sound in our experiments.

There is only a single wire between the Observatory and Cape Town; some little difficulty was therefore experienced in making the necessary arrangements, without any interference with the 1 o'clock current to Port Elizabeth. I have adopted the following plan, which was brought into successful operation on 1871, February 27. It would, however, have been quite impossible for me to have had these experiments made, without an encroachment upon the time of the Observatory staff which could not have been sanctioned, had it not been for the assistance of J. DEN, Esq., the acting manager of the Cape Telegraph Company. I am indebted to Mr. DEN for the preparation of a good earth near the gun, for the assistance of one of the gentlemen attached to the telegraph office, Mr. KIRBY, who has made all the observations at the Cape-Town end, and for a general superintendence of the arrangements in Cape Town. Mr. KIRBY stands at a distance of 641 feet from the gun, near an earth whose connexion with the single main wire is broken at a tapping-piece which Mr. KIRBY, at the time of the experiments, holds in his hand. A small battery is arranged at the Observatory with one pole to earth

through the chronograph coil, and the other connected with the Cape-Town wire through a tapping-piece similar to that used by Mr. KIRBY. At 1 o'clock the observer at the Observatory (Mr. MANN) connects the local battery with the main line: this current is arranged so that it merely assists the main time-ball current. Mr. MANN holds down his tapping-piece until three seconds after 1 o'clock, and thus affords a connexion through the chronograph coils to register Mr. KIRBY's signal. When the current has passed the telegraph office in Cape Town, the connexion is broken at that office. Mr. KIRBY's distance from the gun has been arranged so as to allow of this being done before the sound reaches his station. The line after the breaking of the connexion at Cape Town is complete except at Mr. KIRBY's tapping-piece. When the sound reaches Mr. KIRBY's station he completes the circuit, and his observation is registered on the Observatory chronograph. Mr. KIRBY then holds down his tapping-piece for half a minute, to make earth for the observer at the Observatory station. The connexion at the Observatory station is broken, as before stated, at three seconds after 1 o'clock. When the sound reaches the Observatory, about $13^{s}\cdot 2$ after Mr. KIRBY's observation, the Observatory tapping-piece is again connected, and the time of the sound reaching this station recorded on the chronograph. Time-signals are then sent to check the loss of time of gun-fire, but not as bearing on the determination of the velocity of sound, the results for which are quite independent of any loss of time at the gun, or of any errors of rate except that of the chronograph between seconds of the transit-clock and of the transit-clock for about 13^{s}.

The observations have been made on all the days since February 27 upon which Mr. KIRBY's services were available without any interference with his regular duties. The observations will be found in Table I.

The results have been corrected for the effects of the motion of the air upon the difference in time between the sound reaching Mr. KIRBY's station and its reaching the Observatory, with velocities of the wind found from a set of ROBINSON's cups.

To reduce the equations of condition to a linear form corrections have been applied for the second and third terms of the expansion of $\sqrt{1+\alpha\theta}$, where α is the coefficient of the elasticity of air under a constant volume for a degree FAHRENHEIT of temperature, and θ is the excess of the temperature at the time of the experiment above 32°. The observed differences have also been diminished by $-0^{s}\cdot 09$ for the effects of personal equation between Mr. MANN and Mr. KIRBY under the circumstances of these observations.

This personal equation has been found as follows:—A gun was fired at such a distance from the Observatory that the sound was heard with about the same degree of distinctness as the ordinary time-ball gun at the Castle. This was at a distance of 1483 feet from the Observatory. Mr. KIRBY was placed at a distance of 162 feet from the gun. From previous determinations of the velocity of sound, or from the first approximate result of the present experiments, we can compute with great accuracy the difference in time, at the temperature of the air at the time of observation, of the sound reaching

Mr. KIRBY near the gun and Mr. MANN at the Observatory. The computed difference was $1^{s}\cdot177$; but the observed difference, with the same observers and with the same tapping-pieces as those used in the principal experiments, was $1^{s}\cdot265$: this was the result from twelve accordant observations. The difference $0^{s}\cdot09$ has been applied to all the observed results.

This correction depends more upon want of sensibility in picking up and recognizing faint sounds, than upon mere habit of making contacts. When the observers were reversed and Mr. KIRBY stationed at the Observatory and Mr. MANN near the gun, the observed difference appeared still too large, but in this case by $0^{s}\cdot20$. It is clear that such personal equations are not eliminated by an interchange of observers nor by return signals.

The equations of condition appear in Table II. The times given are those observed corrected for the motion of the air, the second and third terms of the effects of temperature above 32°, and for personal equations. In these equations

$$x=\frac{14808\cdot5 \text{ feet}}{\mathrm{V}},\ y=\frac{\alpha x}{2},\ \mathrm{V}=\text{velocity of sound at } 32^{\circ}.$$

The solution of these equations gives

$$\mathrm{V}=1090\cdot6 \text{ feet per second,}$$
$$\alpha=0\cdot0019.$$

REGNAULT'S value of α is $0\cdot0020$.

The agreement between the value of α deduced from these experiments and REGNAULT'S value is so close that the difference between these values would scarcely be appreciable within the limits of variation of temperature in our experiments. The whole of the results have been given equal weights. It has not appeared necessary to attempt any discrimination between the results in the present paper. There appears, indeed, but little difference between the residuals as dependent upon the corrections for the motion of air. I have grouped the residuals into two classes according to the dampness of the air; but there appears no difference in the velocity, as dependent upon dampness, appreciable within the limits of these experiments, either when referred to tension or humidity. The mean residual for each group nearly vanishes. The whole of the measurements of the distances involved have been made by Mr. MANN. The observations of the regular series from February 27 have been made by Mr. KIRBY at the Cape-Town end, near the gun, and by Mr. MANN at the Observatory. The arrangements for the experiments, galvanic and otherwise, the determination of the personal equations, and the discussion of the results have been made by myself.

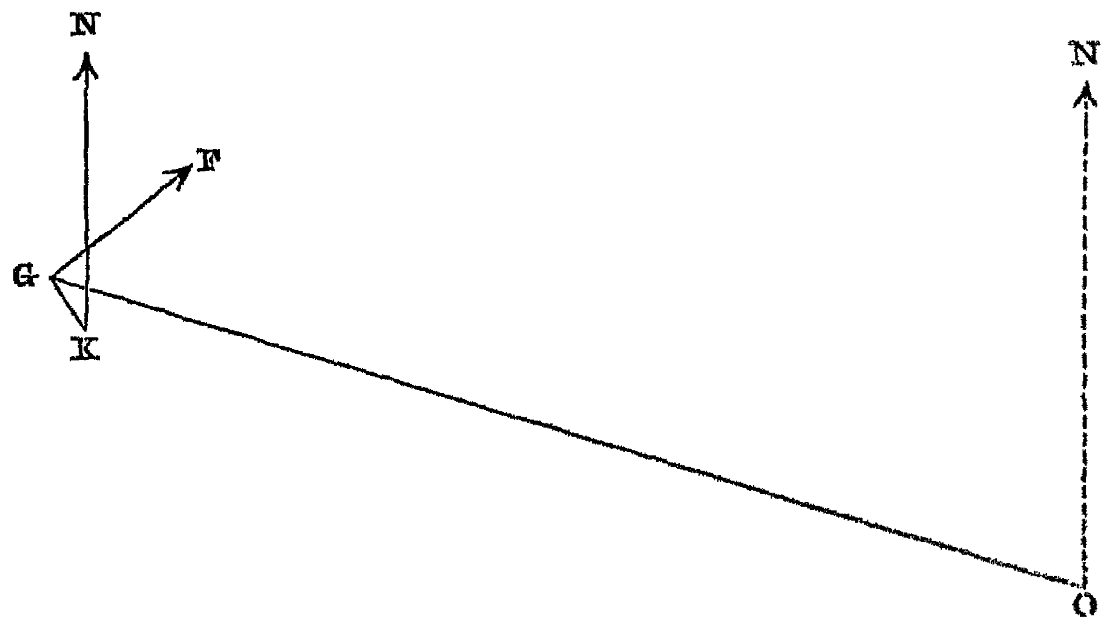
TABLE I.—Experiments for the Determination of the Velocity of Sound.

No of Expt.	Date.	Thermometers.		Barometer.	Wind.		Observed diff.	Correction for motion of air.	Diff. corrected for motion of air.	Resi comp — serv
		Dry.	Wet.		Direction, Az.	Velocity, in miles per hour.				
	1871.	°	°	in.	°		s.	s.	s.	s.
1.	Feb. 27 ……	80·4	66·6	30·036	188	7	13·10	−0·01	13·09	−0·
2.	Feb. 28 ……	77·6	69·8	29·986	158	9	13·32	−0·09	13·23	−0·
3.	Mar. 1 ……	69·0	61·1	30·222	173	25	13·53	−0·14	13·39	−0·
4.	Mar. 2 ……	79·4	63·0	30·193	177	18	13·22	−0·08	13·14	−0
5.	Mar. 3 ……	88·1	66·7	30·000	326	4	12·88	+0·05	12·93	+0
6.	Mar. 4 ……	75·3	67·4	30·067	186	19	13·29	−0·04	13·25	−0
7.	Mar. 6 ……	71·6	61·8	30·152	175	32	13·46	−0·17	13·29	−0
8.	Mar. 7 ……	82·1	65·2	30·084	163	9	13·05	−0·08	12·97	+0·
9.	Mar. 9 ……	74·4	67·5	30·130	315	9	12·81	+0·13	12·94	+0
10.	Mar. 23 ……	69·0	57·3	30·194	171	12	13·26	−0·08	13·18	+0
11.	Mar. 24 ……	71·9	61·0	30·229	275	7	13·15	+0·12	13·27	0
12.	Mar. 27 ……	82·1	64·5	29·964	315	5	12·95	+0·07	13·02	+0
13.	Mar. 30 ……	58·9	52·4	30·128	213	10	13·16	+0·06	13·22	+0
14.	Mar. 31 ……	65·7	59·5	30·286	275	5	13·32	+0·09	13·41	−0
15.	April 1 ……	70·2	63·7	30·176	180	18	13·36	−0·07	13·29	−0
16.	April 4 ……	74·7	63·3	29·929	328	7	12·84	+0·09	12·93	+0
17.	April 5 ……	68·0	63·5	29·988	302	10	13·02	+0·16	13·18	+0
18.	April 6 ……	69·0	62·6	30·218	281	9	13·13	+0·16	13·29	−0
19.	April 11 ……	80·0	65·4	30·150	152	9	13·19	−0·10	13·09	0
20.	April 12 ……	77·0	66·2	30·146	158	14	13·27	−0·14	13·13	0
21.	April 13 ……	71·4	63·7	30·050	167	15	13·38	0·11	13·27	0
22.	April 15 ……	70·5	63·8	30·216	0	1	12·87	0·00	12·87	+0
23.	April 17 ……	64·1	60·1	30·060	318	5	13·44	+0·08	13·52	−0
24.	April 25 ……	58·4	54·1	30·074	121	3	13·42	0·05	13·37	−0
25.	April 27 ……	64·0	58·0	30·336	270	2	13·19	+0·03	13·22	+
26.	April 28 ……	62·5	55·6	30·280	315	9	12·82	+0·13	12·95	+
27.	April 29 ……	67·8	55·3	30·262	158	9	13·43	−0·09	13·34	−
28.	May 1 ……	83·0	60·8	30·056	282	11	12·92	+0·19	13·11	−
29.	May 6 ……	65·0	60·3	30·037	313	2	13·64	+0·02	13·66	0
30.	May 8 ……	62·3	59·1	30·028	321	9	13·22	+0·13	13·35	
31.	May 9 ……	62·6	59·5	29·942	357	8	13·19	+0·04	13·23	+
32.	May 12 ……	66·4	58·9	30·006	279	11	13·09	+0·19	13·28	−
33.	May 16 ……	61·2	59·3	29·924	321	7	12·95	+0·10	13·05	+
34.	May 20 ……	61·2	55·2	30·136	343	6	13·16	+0·05	13·21	+
35.	May 23 ……	68·2	55·6	30·128	315	4	13·24	+0·06	13·30	
36.	June 6 ……	55·6	50·4	30·050	264	14	12·99	+0·23	13·22	+
37.	June 9 ……	61·7	56·1	30·176	304	11	13·15	+0·18	13·33	
38.	June 26 ……	53·4	51·2	30·270	197	15	13·50	+0·02	13·52	

TABLE II.—Equations of Condition.

	s
1.	$x - 48·4\,y = 12·96$
2.	$x - 45·6\,y = 13·10$
3.	$x - 37·0\,y = 13·27$
4.	$x - 47·4\,y = 13·01$
5.	$x - 56·1\,y = 12·78$
6.	$x - 43·3\,y = 13·12$
7.	$x - 39·6\,y = 13·17$
8.	$x - 50·1\,y = 12·83$
9.	$x - 42·4\,y = 12·82$
10.	$x - 37·0\,y = 13·06$
11.	$x - 39·9\,y = 13·15$
12.	$x - 50·1\,y = 12·88$
13.	$x - 26·9\,y = 13·12$
14.	$x - 33·7\,y = 13·30$
15.	$x - 38·2\,y = 13·17$
16.	$x - 42·7\,y = 12·80$
17.	$x - 36·0\,y = 13·06$
18.	$x - 37·0\,y = 13·17$
19.	$x - 48·0\,y = 12·96$
20.	$x - 45·0\,y = 13·00$
21.	$x - 39·4\,y = 13·15$
22.	$x - 38·5\,y = 12·75$
23.	$x - 32·1\,y = 13·41$
24.	$x - 26·4\,y = 13·27$
25.	$x - 32·0\,y = 13·11$
26.	$x - 30·5\,y = 12·84$
27.	$x - 35·8\,y = 13·22$
28.	$x - 51·0\,y = 12·97$
29.	$x - 33·0\,y = 13·55$
30.	$x - 30·3\,y = 13·24$
31.	$x - 30·6\,y = 13·12$
32.	$x - 31·4\,y = 13·17$
33.	$x - 29·2\,y = 12·94$
34.	$x - 29·2\,y = 13·10$
35.	$x - 36·2\,y = 13·18$
36.	$x - 23·6\,y = 13·12$
37.	$x - 29·7\,y = 13·22$
38.	$x - 21·4\,y = 13·42$

From which we find $x = 13·578$ and $y = 0·0129$.



O is the position of the observer at the Observatory.

K is the position of the observer near the gun G.

F indicates the direction of the gun.

N, N point north.

G O = 15449 feet; G K = 640·5 feet.

Angle O G K = 36° 48′; G O N = 76° 2′.

II. *Magnetic Survey of the East of France in* 1869. *By the Rev.* STEPHEN J. PERRY. *Communicated by the President.*

Received July 13,—Read November 23, 1871.

Magnetic Survey of the East of France, 1869.

THIS survey, which occupied a considerable portion of the months of August and September 1869, is a continuation of the series of observations made in the west of France during the preceding year. The instruments used were the same on both occasions, the only changes made for the second expedition being (1°) the substitution of a theodolite by JONES in lieu of COOKE's transit-theodolite, which was slightly too heavy for carrying in the hand, and (2°) the procuring, through the kindness of Dr. STEWART, a second tripod stand similar to our own, which rendered the series of observations with two observers much more rapid than on the previous occasion. The observations were undertaken, as before, by the Rev. W. SIDGREAVES and myself, the Vibrations and Deflections falling to his share, and the Declination and Chronometer comparisons remaining in my hands, whilst the Dip was in general observed by both. The method of reduction is almost identical with that adopted for the observations taken in the west of France.

The geographical positions of the different stations have been calculated, as far as possible, from the data given in the 'Connaissance des Temps,' but where this could not be done I have had recourse to the most reliable sources of information at my command. For the accurate determination of the positions of Mont Rolland (near Dôle), of N. D. de Myans (near Chambéry), of Mongré (near Villefranche-sur-Soane), of Iseure (near Moulins), and of our station at Marseilles I am indebted to the kindness of the Rev. N. LARCHER, S.J., Membre de la Société Météorologique de France. The coordinates of Vaugirard were readily obtained from a good map of Paris, and for Issenheim and Monaco I have to depend on CASSINI's 'Carte Générale de la France' and on PHILIP's 'Imperial Atlas.' The Imperial Observatory at Paris is chosen as the natural position for the origin of coordinates, in lieu of our central station of observation at Vaugirard, which lies on the outskirts of the city; the resulting mean values will thus require no correction, and will be immediately comparable with those of most other observers.

TABLE I.

Station.	Latitude.	Longitude.	Difference in miles of Latitude.	Difference in miles of Longitude.	Place of observation.
	° ′ ″	m s			
Paris Observatory	48 50 11	0 0			
Vaugirard	48 50 2·5	− 0 10·4	− 0·2	− 2·1	Garden of College.
Rheims	49 15 15	+ 6 47	+ 29	+ 77	Place Ruinart.
Metz	49 7 14	+15 22	+ 20	+174	Coll. S. Clement.
Strasburg	48 34 57	+21 40	− 18	+248	9 Rue des Juifs.
Issenheim	48 0 32	+19 49	− 57	+228	Garden of College.
Mont Rolland	47 8 30	+12 34	−117	+148	Château.
Dôle	47 5 33	+12 38	−120	+149	[illegible]
Dijon	47 19 19	+10 48	−105	+127	[illegible]
Lyons	45 45 45	+ 9 57	−212	+120	[illegible]
Avignon	43 57 13	+ 9 53	−337	+123	62 [illegible]
Marseilles	43 17 55	+12 10	−382	+153	[illegible]
Monaco	43 43 2	+20 21	−352	+255	[illegible]
Montpellier	43 36 44	+ 6 10	−361	+ 77	[illegible]
Grenoble	45 11 12	+13 34	−252	+166	[illegible]
N. D. de Myans	45 30 50	+14 36	−230	+177	[illegible]
Mongré	45 59 25	+ 9 29	−197	+114	Garden of College.
St. Etienne	45 26 9	+ 8 13	−235	+100	Collège S. Michel.
Clermont Ferrand	45 46 46	+ 3 0	−211	+ 36	College.
[illegible]	46 33 59	+ 4 4	−157	+ 48	[illegible]
[illegible]	50 22 15	+ 2 59	+106	+ 33	[illegible]
[illegible]	50 43 33	− 2 54	+131	− 32	[illegible]

The Magnetic Dip.

The Dip observations were made with three different needles at each station with the following results:—

TABLE II.

Station.	Date.	G. M. T.	Number of readings. 1.	2.	3.	Dip. No. 1.	No. 2.	No. 3.	
	1869.	h m					° ′ ″		
Vaugirard	Aug. 6	10 52 A.M.	36	...	34	65 52 12	....	65 49 2	
		11 47 A.M.							
	„ 7	8 28 A.M.	...	32	...	....	65 46 50	....	65 49 21
Rheims	„ 10	8 50 A.M.	32	...	...	65 57 43			
		10 8 A.M.	...	34	...	....	65 56 34		
		11 10 A.M.	...	...	38	....	....	65 48 15	65 54 11
Metz	„ 12	9 28 A.M.	32	...	...	65 31 37			
		2 5 P.M.	...	36	...	....	65 20 24		
		3 44 P.M.	...	...	32	....	....	65 24 29	65 25 30
Strasburg	„ 14	4 35 P.M.	...	...	38	....	....	64 39 33	
	„ 15	2 58 P.M.	36	...	...	64 43 32			
		5 40 P.M.	...	36	...	....	64 34 25	....	64 39 10
Issenheim	„ 17	9 50 A.M.	36	...	...	64 38 39			
		11 0 A.M.	...	34	...	....	64 28 23		
		2 37 P.M.	...	...	32	....	....	64 35 4	64 34 2
Mont Rolland	„ 19	4 14 P.M.	36	...	...	64 13 29	....	....	64 13 29
Dôle	„ 19	9 9 A.M.	32	...	...	64 15 18			
	„ 20	9 24 A.M.	...	32	...	....	64 8 11		
		11 0 A.M.	...	...	34	....	....	64 8 35	
Dijon	„ 21	10 15 A.M.	32	...	...	64 28 4			
		2 56 P.M.	...	32	...	....	64 20 3		
		4 21 P.M.	...	...	38	....	....	64 19 3	64 22 23
Lyons	„ 23	9 3 A.M.	34	...	...	63 12 33			
		9 53 A.M.	...	36	...	....	63 15 1		
		10 55 A.M.	...	...	38	....	....	63 14 17	63 13 57
Avignon	„ 25	8 30 A.M.	36	...	...	61 44 32			
		9 30 A.M.	...	38	...	....	61 37 12		
		11 20 A.M.	...	...	32	....	....	62 3 17	

TABLE II. (continued).

:ation.	Date.	G. M. T.	Number of readings. 1.	2.	3.	Dip. No. 1.	No. 2.	No. 3.	Mean.
	1869.	h m							
Marseilles	Aug. 27	9 23 A.M.	34	...	...	60° 31′ 0″			
		10 28 A.M.	...	34	...	....	60° 28′ 20″		
		11 28 A.M.	...	...	34	....	....	60° 37′ 52″	60° 32′ 24″
Monaco	" 29	9 50 A.M.	34	...	...	61 21 47			
		11 10 A.M.	...	34	...	....	61 15 21		
		3 33 P.M.	...	...	38	....	....	61 22 34	61 19 54
Montpellier	" 31	9 10 A.M.	40	...	...	61 35 0			
		10 5 A.M.	...	32	...	....	61 39 25		
		4 15 P.M.	...	...	38	....	....	61 29 33	61 34 39
Grenoble	Sept. 3	10 27 A.M.	34	...	...	62 57 23			
		11 10 A.M.	...	34	...	....	62 47 52		
		4 28 P.M.	...	...	48	....	....	62 50 48	62 52 1
N. D. de Myans......	" 4	1 50 P.M.	32	...	...	62 55 37			
		3 28 P.M.	...	32	...	....	62 47 58		
		4 52 P.M.	...	...	40	....	....	62 47 9	62 50 15
Mongré	" 7	8 5 A.M.	46	...	...	63 27 40			
		9 10 A.M.	...	38	...	....	63 30 20		
		10 58 A.M.	...	...	42	....	....	63 24 57	63 27 39
mne	" 8	10 13 A.M.	36	...	...	63 5 7			
		11 10 A.M.	...	34	...	....	62 59 7	63 0 28	63 1 34
	" 9	8 12 A.M.	...	...	34				
nt	" 10	10 15 A.M.	42	...	...	63 26 5			
	" 11	8 15 A.M.	...	34	...	....	63 44 38		
		9 10 A.M.	...	...	34	....	....	63 32 2	63 34 15
Moulins...............	" 12	9 13 A.M.	31	...	...	64 4 55			
		2 40 P.M.	...	32	...	....	64 18 1		
		4 23 P.M.	...	...	34	....	....	63 45 12	64 2 43
Vaugirard	" 14	9 16 A.M.	32	...	...	65 54 43			
		10 10 A.M.	...	36	...	....	66 12 0		
		11 8 A.M.	...	...	34	....	....	65 48 57	65 58 33
....	" 17	9 55 A.M.	36	...	...	66 46 44			
		11 35 A.M.	...	38	...	....	66 43 29		
		12 40 P.M.	...	...	32	....	....	66 44 7	66 44 47
Boulogne	" 19	3 2 P.M.	32	...	...	67 3 5			
		4 9 P.M.	...	32	...	....	67 11 42		
		5 45 P.M.	...	...	34	....	....	67 0 55	67 5 14

The observations furnish the following equations, which determine the inclination of the isoclinals to the prime meridian and their distance apart:—

$$5\cdot903=\delta-\ \ 77x-\ \ 29y$$
$$5\cdot425=\delta-174x-\ \ 20y$$
$$4\cdot653=\delta-248x+\ \ 18y$$
$$4\cdot567=\delta-228x+\ \ 57y$$
$$4\cdot225=\delta-148x+117y$$
$$4\cdot178=\delta-149x+120y$$
$$4\cdot373=\delta-127x+105y$$
$$3\cdot233=\delta-120x+212y$$
$$1\cdot806=\delta-123x+337y$$
$$0\cdot540=\delta-153x+382y$$
$$1\cdot332=\delta-255x+352y$$
$$1\cdot578=\delta-\ \ 77x+361y$$
$$2\cdot867=\delta-166x+252y$$
$$2\cdot838=\delta-177x+230y$$

$$3{\cdot}461=\delta-114\,x+197\,y$$
$$3{\cdot}026=\delta-100\,x+235\,y$$
$$3{\cdot}571=\delta-\ \ 36\,x+211\,y$$
$$4{\cdot}045=\delta-\ \ 48\,x+157\,y$$
$$6{\cdot}746=\delta-\ \ 33\,x-106\,y$$
$$7{\cdot}087=\delta+\ \ 32\,x-131\,y.$$

These equations of condition combine to form the three simultaneous equations,—

$$\begin{aligned} 75{\cdot}454 &= \quad 20\delta-\ \ 2521x+\ \ 3057y, \\ -8544{\cdot}730 &= -2521\delta+421413x-447498y, \\ 6571{\cdot}180 &= \quad 3057\delta-447498x+910595y, \end{aligned}$$

which give as the most probable values of the three unknowns—

$$\begin{aligned} \delta &= \ \ 5{\cdot}7816, \\ x &= \ \ 0{\cdot}0028495, \\ y &= -0{\cdot}0107928. \end{aligned}$$

Thus the mean value of the Dip at the central station is $65^\circ{\cdot}7816$; whilst the distance between the isoclinals that differ by $30'$ is 44·8 miles, r being $=0^\circ{\cdot}01116$; and the angle formed by the isoclinals with the meridian is $-75^\circ\ 14'\ 34''$, *i. e.* their direction is from N. 75° 14′ 34″ E. to S. 75° 14′ 34″ W.

The substitution of the above values of δ, x, and y in the equations of condition forms the Table by which we can determine the most probable error in a single observation or in the mean.

TABLE III.

	Observed Dip.	Computed Dip.	Error.
Rheims	65·903	65·876	+0·027
Metz	65·425	65·502	−0·077
Strasburg	64·653	64·883	−0·230
Issenheim	64·567	64·527	+0·040
Mont Rolland	64·225	64·097	+0·128
Dôle	64·178	64·062	+0·116
Dijon	64·373	64·287	+0·086
Lyons	63·233	63·152	+0·081
Avignon	61·806	61·795	+0·011
Marseilles	60·540	61·223	−0·683
Monaco	61·332	61·256	+0·076
Montpellier	61·578	61·667	−0·089
Grenoble	62·867	62·597	+0·270
N. D. de Myans	62·838	62·796	+0·042
Mongré	63·461	63·331	+0·130
St. Etienne	63·026	62·961	+0·065
Clermont	63·571	63·403	+0·168
Moulins	64·045	63·951	+0·094
Douay	66·746	66·832	−0·086
Boulogne	67·087	67·287	−0·200

We thus find that the probable errors of any single observation, or rather of the mean value at any single station, $= \pm 0{\cdot}6745 \sqrt{\frac{0{\cdot}765507}{19}} = \pm 0{\cdot}13538$, whilst that of the mean from all the observations $= \pm 0{\cdot}030274$.

The large error at Marseilles will probably be due to the difficulty experienced in finding a convenient site for the observations.

If, now, we turn to the series of observations taken at some of the above stations by Dr. LAMONT, and reduced to the epoch of Jan. 1st, 1858, and if we consider the epoch Sept. 1st, 1869 as common to all stations of our Survey (which we are able to do without sensible error), we arrive at the following Table for determining the secular variation of the Dip in the east of France:—

TABLE IV.

Station.	Dip. Jan. 1, 1858.	Dip. Sept. 1, 1869.	Diff. of Epoch.	Diff. of Dip.	Yearly rate of decrease.	Dip Jan. 1, 1869.
Clermont	64°·202	63°·571	$11\frac{2}{3}$	−0°·631	−0°·054	63°·607
Dijon	64·917	64·373	„	−0·544	−0·047	64·409
Marseilles	61·675	60·540	„	−1·135	−0·097	60·576
Montpellier ...	62·255	61·578	„	−0·677	−0·058	61·614
Moulins	64·723	64·045	„	−0·678	−0·058	64·081
Paris	66·442	65·823	„	−0·619	−0·053	65·859
		Mean (omitting Marseilles)			−0·054	

Comparing this mean annual change with $-0°{\cdot}045$, the rate for 1858 as deduced by LAMONT, we find the decrease to be accelerated annually by $-0°{\cdot}00082$, which agrees closely with the acceleration for the period from 1780 to 1830, which General SABINE gives as $-0{\cdot}00085$.

In our previous discussion of the series of observations taken in 1868 in the west of France, the deduced yearly rate of decrease in the Dip was found to be 0·062; the Dip would therefore seem to be decreasing rather more rapidly in the west than in the east of France.

In the Table of the Dip observations it will be noticed that at a few stations the readings differ very considerably from each other; but I have retained them all in forming the equations of condition, as I cannot see a sufficient reason for discarding any, since the same attention as to choice of position and accuracy of observation was maintained throughout. When at any station the readings of two of the needles agree fairly together, but differ much from the third, this could scarcely be considered conclusive against the correctness of the third, unless all three had been observed under precisely similar circumstances of time and place; since it is not impossible that an iron tube or other disturbing cause, of which we could obtain no information, had affected the two first needles and not the third. But to test the correctness of this view, I have solved the equations after omitting the most striking irregularities, viz. the three at Moulins,

No. 3 at Avignon, and No. 2 at Clermont, and I find that these arbitrary exclusions do not tend to improve the results. It is, however, a different case with regard to the two stations of Marseilles and Grenoble, where we were unable to procure very convenient sites for the observations. Omitting, therefore, these two stations in our equations of condition, we obtain

$$\delta=65{\cdot}7658, \qquad r=0{\cdot}0108, \qquad u=-74^\circ\ 10'\ 13''{\cdot}56,$$

with $\pm 0{\cdot}06550$ as the probable error at any single station, the probable error of the mean being $\pm 0{\cdot}01544$. This diminution in the probable errors would seem to warrant the omissions.

Considering the limited time at our disposal we were unable in this survey of France to choose many stations at which Dr. LAMONT had previously observed; but this want of identity of locality may be balanced by a comparison of the general results obtained from all the observations made during the two surveys. Employing precisely the same method to reduce LAMONT'S values for 1858 as has been used above, we arrive at the following results:—

TABLE V.

Epoch.	Dip at Central Station.	Dist. of isoclinals differing by 0°·5.	Angle of isoclinals N.E. of meridian.	Number of observations.
	°	miles.	° ′ ″	
Jan. 1, 1858, W.	66·6291	40·36	70 23 25	16
Jan. 1, 1858, E.	66·4640	44·44	72 44 33	15
Sept. 1, 1868, W.	65·8796	43·84	73 32 50	13
Sept. 1, 1869, E.	65·7816	44·80	75 14 34	20

We thus obtain 0°·0703 as the annual variation of the Dip in the west of France, whilst in the east it only varies annually 0·0585; and the isoclinals appear to be receding much more rapidly from the meridians in the west than in the east.

We next proceed to discuss the observations for determining the lines of equal intensity.

TABLE VI.

Station.	Date.	G. M. T.	Temp.	Time of one vibration.	Log mX.
		h m	°		
Vaugirard	Aug. 6	2 37 P.M.	69·7	5·164666	0·29102
		2 41	69·3	5·165396	0·29087
		2 45	69·1	5·165825	0·29081
Rheims	" 10	7 3 P.M.	59·6	5·165342	0·28975
		7 8	59·7	5·165250	0·28976
		7 12	59·3	5·165158	0·28976
Metz	" 12	12 25 P.M.	63·0	5·141960	0·29391
		12 29	64·3	5·141916	0·29401
		12 33	64·1	5·141875	0·29399
Strasburg	" 14	4 55 P.M.	70·0	5·084250	0·30438
		5 0	68·8	5·084588	0·30423
		5 4	67·6	5·084825	0·30411
Issenheim	" 17	2 4 P.M.	65·0	5·06998	0·30653
		2 8	65·2	5·06990	0·30656
		2 12	65·4	5·06971	0·30660
Mont Rolland	" 19	2 13 P.M.	64·3	5·03573	0·31227
		2 18	64·4	5·03645	0·31216
		2 22	64·5	5·03730	0·31202
Dôle	" 20	8 2 A.M.	60·4	5·03900	0·31069
		8 6	61·2	5·03903	0·31152
		8 10	62·0	5·03928	0·31152
Dijon	" 21	2 35 P.M.	77·7	5·06046	0·30823
		2 39	77·6	5·06044	0·30822
		2 44	77·5	5·06030	0·30841
Lyons	" 23	2 25 P.M.	77·5	4·97529	0·32367
		2 29	77·0	4·97502	0·32367
		2 33	76·5	4·97475	0·32369
Avignon	" 25	11 13 A.M.	80·2	4·87966	0·34095
		11 34	81·3	4·88105	0·34035
Marseilles	" 27	2 50 P.M.	79·8	4·82787	0·34982
		3 14	79·7	4·82735	0·34991
Monaco	" 29	10 48 A.M.	80·6	4·86301	0·34360
		10 52	80·6	4·86277	0·34364
		10 56	80·7	4·86264	0·34367
Montpellier	" 31	3 43 P.M.	79·7	4·87120	0·34219
		3 47	80·3	4·87192	0·34210
		3 51	80·9	4·87266	0·34201
Grenoble	Sept. 3	2 36 P.M.	76·3	4·982880	0·32211
		2 58	74·6	4·981167	0·32228
		3 2	74·6	4·980875	0·32233
		3 6	74·2	4·981729	0·32216
N. D. de Myans.........	" 4	3 27 P.M.	69·9	4·954608	0·32663
Mongré	" 7	10 27 A.M.	71·6	4·994708	0·31984
St. Etienne..............	" 8	5 32 P.M.	70·5	4·964875	0·32483
		5 35	69·3	4·964740	0·32478
		5 40	68·0	4·964521	0·32473
Clermont	" 10	4 53 P.M.	65·1	4·994458	0·31931
		5 12	62·4	4·995460	0·31896
Moulins	" 12	11 26 A M.	70·0	5·036300	0·31238
		11 44	69·7	5·035200	0·31256
		11 47	69·7	5·034379	0·31270
		11 52	69·7	5·033360	0·31287
Vaugirard	" 15	6 0 P.M.	63·8	5·167092	0·28974
		6 52	64·0	5·167541	0·28967
		6 56	63·9	5·167288	0·28982
Douay......................	" 17	9 27 A.M.	62·5	5·245416	0·27660
		9 31	62·5	5·245062	0·27666
		9 36	62·4	5·244708	0·27671
Boulogne	" 19	5 23 P.M.	58·9	5·272550	0·27192
		5 43	57·7	5·272808	0·27180
		5 47	57·4	5·272748	0·27178
		5 52	57·0	5·272758	0·27176

The following observations of Deflection at 1 foot and 1·3 foot serve as the complement of the above Table of vibrations, and furnish us with the Horizontal Component of the Earth's Magnetic Intensity.

TABLE VI. (bis).

Station.	Date.	G. M. T.	Temp.	Dist. of magnets.	Observed deflection.	Log $\frac{m}{x}$.
		h m	°		° ′ ″	
Vaugirard	Aug. 6	4 5 P.M.	67·4	1·0	13 11 34	9·06047
		4 17	68·3	1·3	5 58 5	9·06040
Rheims	„ 10	6 1 P.M.	60·2	1·3	5 58 9	9·05989
		6 14	59·8	1·0	13 12 0	9·06015
Metz	„ 12	3 32 P.M.	70·0	1·0	13 3 29	9·05628
		3 49	70·2	1·3	5 54 44	9·05647
		6 39	54·4	1·0	13 6 33	9·05684
Strasburg	„ 14	5 10 P.M.	66·5	1·0	12 46 54	9·04688
		5 21	65·9	1·3	5 47 9	9·04681
Issenheim	„ 17	3 41 P.M.	64·4	1·0	12 43 31	9·04485
		3 56	64·2	1·3	5 45 41	9·04485
Mont Rolland	„ 19	3 40 P.M.	64·1	1·0	12 32 28	9·03859
		3 51	63·5	1·3	5 40 55	9·03878
Dôle	„ 20	9 52 A.M.	64·8	1·0	12 34 5	9·03956
		10 4	65·1	1·3	5 41 35	9·03975
Dijon	„ 21	3 59 P.M.	76·4	1·0	12 37 1	9·04209
		4 12	76·7	1·3	5 42 43	9·04193
Lyons	„ 23	3 50 P.M.	73·4	1·0	12 11 30	9·02720
		4 1	72·7	1·3	5 31 24	9·02721
Avignon	„ 25	5 9 P.M.	81·0	1·0	11 42 10	9·01028
		5 19	80·7	1·3	5 18 22	9·01046
Marseilles	„ 27	4 33 P.M.	76·5	1·0	11 28 18	9·00138
		4 44	76·4	1·3	5 11 52	9·00119
Monaco	„ 29	2 37 P.M.	78·1	1·0	11 36 47	9·00676
		2 50	77·9	1·3	5 15 55	9·00690
Montpellier	„ 31	5 3 P.M.	76·4	1·0	11 40 55	9·00916
		5 15	76·3	1·3	5 17 51	9·00941
Grenoble	Sept. 3	3 53 P.M.	72·5	1·0	12 14 1	9·02862
		4 5	72·4	1·3	5 32 15	9·02830
N. D. de Myans	„ 4	4 16 P.M.	69·0	1·0	12 5 36	9·02341
		4 47	68·6	1·3	5 28 22	9·02292
Mongré	„ 7	11 14 A.M.	69·3	1·0	12 17 9	9·03019
		11 24	69·8	1·3	5 33 46	9·03007
St. Etienne	„ 8	3 38 P.M.	73·4	1·0	12 8 15	9·02530
		4 8	73·3	1·3	5 29 57	9·02536
Clermont	„ 11	7 58	62·5	1·0	12 20 17	9·03150
		8 8	62·8	1·3	5 35 3	3·03122
Moulins	„ 12	2 35 P.M.	65·5	1·0	12 31 7	9·03793
		2 47	65·5	1·3	5 40 7	9·03791
Vaugirard	„ 14	2 18 P.M.	69·9	1·0	13 12 53	9·06135
		2 27	69·6	1·3	5 58 52	9·06144
Douay	„ 17	10 36 A.M.	64·0	1·0	13 36 14	9·07330
		10 46	65·1	1·3	6 9 10	9·07335
Boulogne	„ 20	9 3 A.M.	58·7	1·0	13 47 34	9·07879
		9 25	59·0	1·3	6 14 18	9·07889

From these Tables, combined with those of the Dip observations, we deduce the following values of the Horizontal and Vertical Components, and of the Total Magnetic Intensity. The last column contains the calculated mean values of the magnetic moment of the deflecting magnet at each station.

TABLE VII.

Station.	H. F.	V. F.	T. F.	m.
Vaugirard	4·1232	9·1840	10·0672	0·47388
Rheims	4·1198	9·2113	10·0907	0·47304
Metz	4·1570	9·0904	9·9958	0·47342
Strasburg	4·2531	8·9782	9·9346	0·47375
Issenheim	4·2743	8·9883	9·9528	0·47393
Mont Rolland	4·3325	8·9719	9·9632	0·47361
Dôle	4·3231	8·9341	9·9251	0·47365
Dijon	4·2974	8·9586	9·9361	0·47339
Lyons	4·4488	8·8195	9·8780	0·47364
Avignon	4·6254	8·6282	9·7897	0·47371
Marseilles	4·7238	8·3629	9·6048	0·47378
Monaco	4·6602	8·5233	9·7142	0·47341
Montpellier	4·6389	8·5713	9·7461	0·47391
Grenoble	4·4348	8·6554	9·7252	0·47358
N. D. de Myans	4·4847	8·7403	9·8236	0·47304
Mongré	4·4143	8·8385	9·8796	0·47314
St. Étienne	4·4641	8·7711	9·8417	0·47321
Clermont	4·4044	8·8613	9·8956	0·47343
Moulins	4·3387	8·9135	9·9134	0·47346
Vaugirard	4·1132	9·1619	10·0429	0·47377
Douay	3·9964	9·3003	10·1226	0·47315
Boulogne	3·9491	9·3428	10·1431	0·47352

These values of H. F., combined with the second members of our previous set of equations, which remain unchanged, will give us the equations of condition for determining the lines of equal Horizontal Intensity. Reducing these equations by the method of least squares, we obtain:—

$$27·3408 = 20\,h - 2521\,x + 3057\,y,$$

$$-3560·9763 = -2521\,h + 421413\,x - 447498\,y,$$

$$4782·1935 = 3057\,h - 447498\,x + 910595\,y;$$

$$\therefore\quad h = \text{H. F.} - 3 = 1·1259,$$

$$x = -0·000317,$$

$$y = \quad 0·001316.$$

Hence $r = 0·00135$, or the lines whose H. F. differs by 0·1 are 73·7 miles apart; and $u = -76°\,27'\,16''·5$, or the direction of the lines is N. 76° 27′ 16″·5 E. to S. 76° 27′ 16″·5 W.

A substitution of these values in our original equations will enable us to form a Table of the computed Horizontal Force for each station.

TABLE VIII.

Station.	Computed H. F.	Observed H. F.	Obs.—Comp.
Paris	4·1259	4·1182	−0·0067
Rheims	4·1121	4·1198	+0·0077
Metz	4·1548	4·1570	+0·0022
Strasburg	4·2282	4·2531	+0·0249
Issenheim	4·2732	4·2743	+0·0011
Mont Rolland	4·3268	4·3325	+0·0057
Dôle	4·3310	4·3231	−0·0079
Dijon	4·3044	4·2974	−0·0070
Lyons	4·4429	4·4488	+0·0059
Avignon	4·6084	4·6254	+0·0170
Marseilles	4·6771	4·7238	+0·0467
Monaco	4·6699	4·6602	−0·0097
Montpellier	4·6254	4·6389	+0·0135
Grenoble	4·5101	4·4348	−0·0753
N. D. de Myans	4·4847	4·4847	0·0000
Mongré	4·4213	4·4143	−0·0070
St. Étienne	4·4669	4·4641	−0·0028
Clermont	4·4150	4·4044	−0·0106
Moulins	4·3477	4·3387	−0·0090
Douay	3·9969	3·9964	−0·0005
Boulogne	3·9434	3·9491	+0·0057

Excluding Paris, which does not enter as a station into our equations of condition, we obtain for the probable error of the mean value of the observed H. F. at any single station

$$0{\cdot}6745\sqrt{\frac{0{\cdot}00956332}{19}}=\pm 0{\cdot}01513,$$

whilst the error of the computed value for the central station will be $\pm 0{\cdot}00338$.

It remains for us to deduce the secular variation of the Horizontal Force from the observations taken at those stations which are common to the two surveys of 1858 and 1869.

TABLE IX.

Station.	H. F., Jan. 1, 1858.	H. F., Sept. 1, 1869.	Diff. of Epoch.	Diff. of H. F.	Yearly rate of increase.	H. F., Jan. 1, 1869.
Clermont	4·3523	4·4044	$11\frac{2}{3}$	+0·0521	+·00447	4·4013
Dijon	4·2385	4·2974	"	+0·0589	+·00505	4·2943
Marseilles	4·6332	4·7238	"	+0·0906	+·00777	4·7207
Montpellier	4·5788	4·6389	"	+0·0601	+·00515	4·6358
Moulins	4·2871	4·3387	"	+0·0516	+·00442	4·3356
Paris	4·0685	4·1182	"	+0·0497	+·00426	4·1151
		Mean (omitting Marseilles)			+·00467	

The yearly rate deduced from the observations of 1858 and 1868 in the west of France was $+0{\cdot}00507$; hence the rate of increase appears to be slower in the east than in the west, whilst the mean rate for the whole of France is identical with that given by Dr. LAMONT for 1858, the yearly acceleration being less than 0·000007.

Were we to omit the observations taken at the stations of Marseilles, where the site was quite exceptional, and of Grenoble, where the geological formation appears very unfavourable for deducing a correct mean value, the solution of the remaining equations would give us a value for r identical with that already obtained, but would induce a very considerable change in the resulting angle between the lines of equal intensity and the prime meridian. The probable errors would be greatly diminished. The several quantities would become

4·1260 for the H. F. at the central station.

$0·00135=r$ and $u=-75° \; 22' \; 35''$.

Probable error at any one station $\pm 0·00654$, and at the central station $\pm 0·00154$.

I will now form a Table, similar to that for the Dip, for comparing the general results obtained during the two surveys of 1858 and 1868–69.

TABLE X.

Epoch.	H. F. at Central Station.	[illegible]	[illegible]	[illegible]
		miles.	° ′ ″	
Jan. 1st, 1858, W.	4·0521	68·0	72 40 51·7	20
Jan. 1st, 1858, E.	4·0707	73·5	78 49 36·0	22
Sept. 1st, 1868, W.	4·1150	71·4	74 25 31·5	13
Sept. 1st, 1869, E.	4·1259	74·1	76 27 16·5	20

We see at once that the lines of equal Horizontal Force lie much closer in the west of France, but that this difference is diminishing rapidly at present, although it still remains considerable. The mean angle formed by these lines with the meridian of Paris is only slightly different for 1858 and for 1868 and 1869, whilst the angle deduced from both sets of observations taken in the east is very much greater than that found for the west; the difference, however, is here again less for 1868–69 than for 1858.

The secular variation for the W. $+0·00590$, and for the E. $+0·00473$, obtained from the preceding Table, agrees well with the results deduced from the few stations which are common to the two surveys.

We next come to the discussion of the values of the Total Force, found by combining the observations of the Dip and Horizontal Force taken at each successive station.

The figures in Table VII. enable us to form at once the required equations of condition, and these combined furnish the three equations,—

$$17·8759=20\,F-2521\,x+3057\,y,$$
$$-2167·3049=-2521\,F+421413\,x-447498\,y,$$
$$2352·5148=3057\,F-447498\,x+910595\,y,$$

whose solution give $F=1·0608$, $x=0·0003444$, $y=-0·0008084$.

Thus the isodynamics that differ by 0·1 are 113·8 miles apart, and they lie at an angle of $66° \; 55' \; 24''·9$ to the N.E. of the geographical meridian. The intensity of the earth's

magnetism at the central station is 10·0608. The probable errors can now be deduced by a comparison of the values computed from the above data with the intensity at each station, found by combining the observations of the Dip and Horizontal Force.

TABLE XI.

Station.	From observed Dip and H. F.	Computed.	Error.
Rheims	10·0907	10·0577	+0·0330
Metz	9·9958	10·0171	−0·0213
Strasburg	9·9346	9·9608	−0·0262
Issenheim	9·9528	9·9362	+0·0166
Mont Rolland	9·9632	9·9152	+0·0480
Dôle	9·9251	9·9125	+0·0126
Dijon	9·9361	9·9322	+0·0039
Lyons	9·8780	9·8381	+0·0399
Avignon..................	9·7897	9·7360	+0·0537
Marseilles	9·6048	9·6993	−0·0945
Monaco	9·7142	9·6884	+0·0258
Montpellier..............	9·7461	9·7425	+0·0036
Grenoble	9·7252	9·7999	−0·0747
N. D. de Myans.........	9·8236	9·8149	+0·0087
Mongré	9·8796	9·8622	+0·0174
St. Etienne	9·8417	9·8364	+0·0053
Clermont	9·8956	9·8778	+0·0178
Moulins	9·9134	9·9174	−0·0040
Douay.....................	10·1226	10·1351	−0·0125
Boulogne	10·1431	10·1777	−0·0346
Paris	10·0551	10·0608	−0·0057

These errors, omitting that for Paris, since it is not included in our equations, give as the probable error at any single station $\pm 0{\cdot}0253$, whilst that for the mean is $\pm 0{\cdot}00566$.

The stations common to the surveys of 1858 and of 1868–69 will furnish us with the data for calculating the secular changes of terrestrial magnetic intensity.

TABLE XII.

Station.	T. F., Jan. 1, 1858.	T. F., Sept. 1, 1869.	Difference of epoch.	Difference of T. F.	Yearly rate of change.
Clermont	10·0007	9·8956	$11\frac{2}{3}$	−0·1051	−0·0090
Dijon	9·9979	9·9361	,,	−0·0618	−0·0053
Marseilles	9·7649	9·6048	,,	−0·1601	−0·0137
Montpellier ...	9·8355	9·7461	,,	−0·0894	−0·0077
Moulins	10·0356	9·9134	,,	−0·1222	−0·0105
Paris	10·1793	10·0551	,,	−0·1242	−0·0106
				Mean............	−0·00947

The secular variation deduced from the general results of all the observations is considerably larger than the above, being 0·0118 for the west and 0·0119 for the east of France. These are obtained from the subjoined Table.

TABLE XIII.

Epoch.	Intensity at Central Station.	Distance between Isodynamics which differ by 0·1.	Angle of Isodynamics N.E. of meridian.	Number of stations.
		miles.		
Jan. 1, 1858, W.	10·1951	91·7	63° 52′ 40″·6	16
Jan. 1, 1858, E....	10·2000	96·9	60 18 43·7	15
Sept. 1, 1868, W.	10·0688	113·9	70 39 17·8	13
Sept. 1, 1869, E.	10·0608	113·8	66 55 24·9	20

It is evident from these figures that the variations of the Dip and Horizontal Force combine to produce a very rapid alteration of the isodynamics, especially by increasing the distance between the lines.

The largeness of the error in the Total Force at Marseilles and Grenoble warrants a recalculation of the results with the omission of these two stations. The following are the values obtained by this reduction:—

T. F. $=10·0566$, $x=0·0003253$, $y=-0·0007253$, $r=0·000795$, $u=65° \; 50' \; 40''·8$.

The probable errors are thus very much diminished, being now only 0·01306 for a single station, and for the mean 0·00308.

The Magnetic Declination.

The determination of this magnetic element, which at a fixed observatory presents but little difficulty, is by far the most troublesome and the least to be relied upon when the observations have to be taken in the course of a magnetic survey. For not only must the magnetic instruments themselves be in perfect condition, as for the other observations, but any unknown change of rate in the chronometer, any error in the determination of the sun's position, is sufficient to introduce a serious inaccuracy in the results, to say nothing of the perturbations so much more frequent and more extensive in this element than in the others.

The Frodsham chronometer used during this survey has given perfect satisfaction, its rate having been remarkably constant during the whole journey, even more so than in 1868. This will be seen from the following comparisons:—

TABLE XIV.

Station.	Date.	G. M. T.	Error.	Daily rate.
		h m s	m s	
Stonyhurst Observatory	July 20	9 21 5·5 P.M.	+5 4·77	s
"	" 21	9 51 25·0 P.M.	+5 6·77	+2·00
"	" 25	9 57 10·0 P.M.	+5 15·71	+2·24
Paris Observatory	Aug. 7	10 20 A.M.	+5 39·65	+1·84
Marseilles Observatory.........	" 27	9 43 A.M.	+6 18·97	+1·966
Paris Observatory	Sept. 14	1 0 P.M.	+6 54·70	+1·985
Stonyhurst Observatory	" 25	7 15 40·5 P.M.	+7 13·30	+1·69
"	Oct. 9	6 54 45·0 P.M.	+7 34·58	+1·52
"	" 24	7 15 15·5 P.M.	+7 57·27	+1·51

The rate appears to have been slowly diminishing from July to October, and to have suffered very little disturbance from the travelling. I was unable during the journey to make more frequent comparisons; but altitudes of the sun were taken as before at each station by way of check, though they were fortunately found to be unnecessary.

The observations for finding the sun's azimuth are much less trustworthy than in the preceding year, owing to a change of instrument. The transit-altazimuth of COOKE, which worked so steadily in 1868, was replaced, on account of its heaviness, by a JONES theodolite, which, though much more portable, had the great disadvantage of being far less steady, and thus interfering very considerably with the accuracy of the results.

In all the observations taken during this survey with the declination needle, the scale of the collimator magnet was inverted twice at each station, so as to render unnecessary any other determination of the zero of the scale, which might accidentally be slightly altered whilst travelling.

In the following Table the first readings of the azimuth of the fixed mark were taken throughout on the theodolite circle, and the second readings on the circle of the unifilar.

TABLE XV.

Station.	Date.	Chronometer.	Error at noon, G. M. T.	Daily rate.	Azimuth of Sun.	Azimuth of mark.	Azimuth of magnet.
		h m s	m s	s			
Rheims	Aug. 10	9 14 3·1 A.M.	+5 45·70	+1·97	169° 52′ 45″	26° 48′ 15″ 178 3 5	188° 52′ 1″
Metz	„ 12	8 33 34·3 A.M.	+5 49·64	„	92 18 45	139 10 15 116 18 10	119 37 59
Strasburg	„ 14	2 35 26·0 P.M.	+5 53·57	„	165 39 45	141 38 0 178 48 0	125 26 38
Issenheim	„ 17	9 18 51·8 A.M.	+5 59·48	„	70 48 30	54 24 0 61 39 10	93 48 21
Dôle	„ 19	9 40 3·3 A.M.	+6 3·42	„	156 32 15	176 53 0 154 6 55	166 12 3
Dijon	„ 21	9 44 21·2 A.M.	+6 7·36	„	25 13 0	136 25 0 173 41 45	93 6 46
Avignon	„ 25	8 36 6·0 A.M.	+6 15·23	„	99 21 45	36 8 30 193 36 30	127 14 53
Marseilles	„ 27	11 50 58·3 A.M.	+6 19·16	+1·98	140 57 0	132 25 15 109 54 0	100 51 1
Monaco	„ 29	9 0 57·0 A.M.	+6 23·10	„	28 21 0	150 17 15 127 45 25	227 54 27
Montpellier	„ 31	8 35 28·1 A.M.	+6 27·04	„	74 35 40	92 30 25 130 4 45	161 12 24
Grenoble	Sept. 3	9 54 42·8 A.M.	+6 32·95	„	8 16 45	61 21 38 158 37 7	130 8 54
N. D. de Myans...	„ 4	1 30 31·9 P.M.	+6 34·92	„	140 8 0	158 17 15 195 34 15	122 18 5
Mongré	„ 7	8 35 32·0 A.M.	+6 40·83	„	21 22 45	70 55 30 108 25 10	103 45 39
St. Etienne	„ 8	9 6 12·8 A.M.	+6 42·80	„	62 53 15	170 13 15 267 42 20	107 51 13
Clermont	„ 10	8 51 30·2 A.M.	+6 46·74	„	53 1 55	109 31 30 146 53 5	131 45 25
Moulins	„ 12	8 36 4·0 A.M.	+6 50·68	„	64 4 0	110 50 45 148 15 25	145 2 26
Paris	„ 14	9 10 35·8 A.M.	+6 54·62	„	171 30 15	107 42 0 265 9 40	122 33 14
Douay	„ 17	11 58 28·9 A.M.	+7 0·56	„	152 27 20	159 14 45 256 45 25	228 56 0
Boulogne	„ 19	3 45 24·7 P.M.	+7 4·52	„	177 12 25	48 51 45 266 19 10	131 45 8

To complete the above, we have to calculate the azimuth of the sun at the time of each observation, which gives us the south point for the several stations. These south points together with the observed angles will then at once furnish the Declinations.

TABLE XVI.

Station.	Azimuth of Sun.	West Declination.
	° ′ ″	° ′ ″
Rheims	58 21 30·0	16 37 4·0
Metz	66 3 34·1	15 52 15·1
Strasburg	61 54 43·3	15 28 23·7
Issenheim	52 25 20·6	15 41 11·3
Dôle	48 24 26·8	15 58 33·8
Dijon	46 52 35·0	16 30 10·0
Avignon	66 21 15·2	15 56 7·2
Marseilles	2 1 58·8	15 34 45·3
Monaco	56 29 55·8	14 24 38·8
Montpellier	65 28 20·7	16 25 56·7
Grenoble	40 18 20·5	15 41 40·5
N. D. de Myans	39 56 14·4	15 3 45·6
Mongré	60 49 3·4	16 49 34·4
St. Étienne	52 16 26·4	14 47 33·4
Clermont	57 42 27·4	16 20 29·9
Moulins	59 55 50·5	16 22 4·5
Paris	50 43 42·6	17 8 23·6
Douay	3 9 41·9	17 52 13·1
Boulogne	64 48 22·8	18 6 16·8

This Table supplies the data from which the three following equations are deduced:—

$$37{\cdot}551 = 18D - 2253\,x + 2728\,y,$$

$$-3727{\cdot}065 = -2253\,D + 385109\,x - 404742\,y,$$

$$4120{\cdot}753 = 2728\,D - 404742\,x + 851962\,y,$$

whose solution gives $D = 3{\cdot}4493$, $x = 0{\cdot}0079430$, $y = -0{\cdot}0024348$.

Therefore the declination at the central station is $17^{\circ}{\cdot}4493$, the distance between the isogonics of places whose declinations differ by $30'$ is $60{\cdot}2$ miles, and the angle formed by the isogonics with the geographic meridian $17^{\circ}\ 2'\ 30''{\cdot}5$ to the N.E.

The Table of errors will show the weight to be given to the various observations.

TABLE XVII.

Station.	Observed Declination.	Computed Declination.	
Rheims	16°·618	16°·908	−0·290
Metz	15·871	16·116	−0·245
Strasburg	15·473	15·435	+0·038
Issenheim	15·687	15·499	+0·188
Dôle	15·976	15·974	+0·002
Dijon	16·503	16·184	+0·319
Avignon..................	15·935	15·652	+0·283
Marseilles	15·579	15·404	+0·175
Monaco	14·411	14·567	−0·156
Montpellier	16·432	15·958	+0·474
Grenoble	15·695	15·518	+0·177
N. D. de Myans.........	15·067	15·583	−0·516
Mongré	16·826	16·064	+0·762
St. Etienne..............	14·793	16·483	−1·690
Clermont	16·342	16·649	−0·307
Moulins	16·368	16·686	−0·318
Douay.....................	17·870	17·445	+0·425
Boulogne	18·105	18·022	+0·083
Paris	17·140	17·449	−0·309

The largeness of these errors is mainly, I think, due to the unsteadiness of the Jones altazimuth, which had been substituted, on account of its lightness, in lieu of the Cooke transit-altazimuth used during the survey of the west. This unfortunately diminishes greatly the value of the results, and makes them scarcely comparable with those obtained for the west of France. The probable error for a single station is found to be $\pm 0{\cdot}35884$, and for the mean $\pm 0{\cdot}08458$. Omitting the two worst results, viz. those for Mongré and St. Etienne, we obtain

$$D=3{\cdot}4989,\ x=0{\cdot}0083462\ y=-0{\cdot}0021920,\ r=0{\cdot}00863,\ u=14^\circ\ 42'\ 57''{\cdot}2;$$

with probable errors of $\pm 0{\cdot}21389$ and $\pm 0{\cdot}05347$.

The results, if we may judge of them by the amount of the probable error, will be still more improved if, besides casting out the two worst results, we correct each individual observation for the disturbance occurring at the time in this magnetic element. The correction to be applied may be obtained from measurements of the Stonyhurst photographic curves, as explained in my former paper on the Survey of the west of France. The almost identical occurrence of these disturbances in neighbouring countries, with regard, at least, to the element under discussion, is now so well established as to render unnecessary any justification of the appliance of such a mode of correction; but, unfortunately for its present efficacy, no disturbance happened during any of the observations that will enable me to smooth very considerably the observed inequalities. From the solution of the equations formed with the corrected observations we obtain

$$D=3{\cdot}4757,\ x=0{\cdot}0082848,\ y=-0{\cdot}0021781,\ r=0{\cdot}00857,\ u=14^\circ\ 43'\ 48''{\cdot}6,$$

with probable errors of $\pm 0{\cdot}19745$ and $\pm 0{\cdot}04936$.

We will now pass on to the consideration of the secular variation of the Declination.

TABLE XVIII.

Station.	Declination, Jan. 1, 1858.	Declination, Sept. 1, 1869.	Difference of Epoch.	Difference of Declination.	Yearly rate of change.	Declination, Jan. 1, 1869.
Clermont	18°·568	16°·342	$11\frac{2}{3}$	−2°·226	−0°·191	16°·460
Dijon	17·932	16·503	"	−1·429	−0·122	16·612
Marseilles	17·068	15·579	"	−1·489	−0·128	15·691
Moulins	18·653	16·368	"	−2·285	−0·196	16·487
Paris	19·605	17·140	"	−2·465	−0·211	17·260
				Mean	−0·1696	

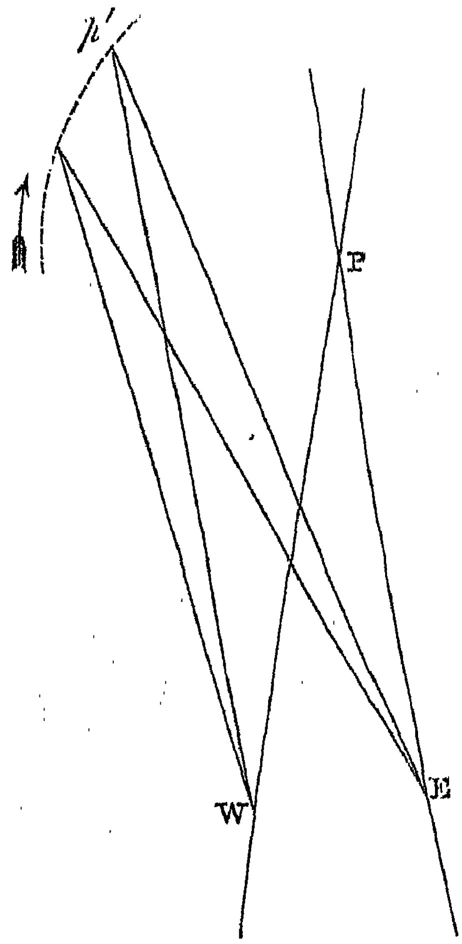
This result is somewhat larger than that found for the west of France, which was −0°·1533; and the greater difference between the results obtained from the observations at the several stations makes the result less trustworthy.

I will next proceed to collect in a single Table the chief results connected with the Isogonics of the surveys of 1858 and 1868–69.

TABLE XIX.

Epoch.	Declination at Central Station.	Distance of Isogonics [illegible] by 0° [illegible]	Angle of Isogonics [illegible]	Number of observations.
		miles.		
Jan. 1, 1858 W.	19°·6390	50·4	22° 18′ 24″·9	18
Jan. 1, 1858 E.	19·6053	46·0	16 37 16·9	17
Sept. 1, 1868 W.	17·9498	44·2	21 41 0·9	13
Sept. 1, 1869 E.	17·4493	60·2	17 2 30	18

This gives as the secular decrease of the Declination in the west and east 0·1583 and 0·1848 respectively, which are somewhat in excess of the values found from the few stations common to both the surveys.



The secular diminution of the Dip and Declination, and the increase of the Horizontal Force, in both the east and west of France, so clearly indicate the actual position of the North magnetic pole, together with its motion round the extremity of the earth's axis of rotation, that we are led to examine whether this same motion of the pole may not also account, at least in part, for the differences observable in the results obtained from the east and west surveys.

In the annexed diagram let P represent the geographical pole, W and E the two portions of the country surveyed, and p, p' the positions of the magnetic pole corresponding to the epochs 1858 and 1869.

If λ stands for the magnetic latitude, and δ for the Dip, we shall have $\tan\delta = 2\tan\lambda$; and consequently the change

of position of the pole from p to p' should cause a greater variation in the Dip at W than at E, W being nearer than E to the magnetic pole. On the other hand, since the line $p\,p'$ is inclined at a greater angle to the meridian E P than to W P, the change of Declination due to the motion from p to p' should be less rapid at W than at E. With regard to the Intensity of the earth's magnetic force, the laws of distribution are too complex and irregular to warrant any certain conclusion in a particular case, unless the conditions of local magnetism are taken fully into account. Comparing these conclusions with the results derived from the observations discussed in this paper, we find a perfect agreement in the case of the Dip and Declination, and the observations of the Horizontal Force tend to show that greater nearness to the pole is combined with increased rate of variation in this element.

Turning, now, our attention from the consideration of the difference between the two sets of values of the magnetic elements to examine the secular changes in the curves of equal Dip, Declination, and Intensity, we do not expect to find a very close agreement between theory and observation. The distribution of the Isoclinals and Isogonics, and still more that of the Isodynamics, is so irregular, that such a slight difference of position as the east and west of France would probably have scarcely any apparent effect upon the resulting values, any small inequality being at least partially veiled by accidental errors from locality or observations. Still, however, as the Isoclinals and Isodynamics are approximately at right angles to the magnetic meridians, we may be justified in the assumption that, as the pole's path $p\,p'$ approaches parallelism to W E, the difference of angle in east and west for both sets of lines will become much less marked. Here, again, we find that the results of the observations taken in France agree well with the assumption made. The Isogonics present a precisely similar coincidence, as might be expected from their position in relation to the pole's actual path.

Since, moreover, $p\,p'$ is more nearly parallel with the Isogonics than with the Isoclinals and Isedynamics, there is a greater fixity in the mean angle for the whole of France in the case of the former lines than in that of the latter.

Lastly, the Isoclinals and Isodynamics are spreading out more quickly in the west than in the east, and there exists at present very little difference in the thickness of these lines in the two portions of the country, both of which conclusions would naturally follow from the fact that the pole is becoming more and more nearly equidistant from the east and west of France. The exceptional case of the Isogonics, which are spreading out in the east and drawing closer in the west, evidently arises mainly from inaccuracy of observation.

A general Table may now be formed of all the magnetic elements, reduced to the epoch Jan. 1, 1869, for the stations in the east of France.

TABLE XX.

	Dip.	Declination.		
Avignon ...	61·841	16·046	4·6224	9·7927
Boulogne	67·126	18·227	3·9458	10·1511
Clermont	63·607	16·460	4·4013	9·9010
Dijon	64·409	16·612	4·2943	9·9418
Dôle	64·213	16·084	4·3201	9·9307
Douay......	66·785	17·991	3·9931	10·1301
Grenoble...	62·903	15·822	4·4317	9·7293
Issenheim	64·601	15·794	4·2714	9·9585
Lyons	63·268	....	4·4454	9·8826
Marseilles	60·576	15·691	4·7207	9·6092
Metz	65·458	15·976	4·1541	10·0012
Monaco ...	61·368	14·524	4·6571	9·7189
Mongré	63·498	16·942	4·4111	9·8853
Montpellier	61·614	16·545	4·6358	9·7512
Mont Rolland ..	64·260	....	4·3295	9·9692
Moulins	64·081	16·487	4·3356	9·9190
N. D. de Myans..	62·875	15·182	4·4815	9·8293
Paris	65·859	17·260	4·1151	10·0618
Rheims	65·936		4·1170	10·0967
St. Etienne........	63·063	14·910	4·4609	9·8472
Strasburg	64·687	15·578	4·2502	9·9405

In forming this Table the observed values have invariably been used, no correction or omission, however much it might tend to smooth down inequalities, being judged admissible. Should any such corrected elements be required, they can readily be obtained from the data furnished by the paper. A similar Table of uncorrected results given in the report of the Survey of the west completes the list of magnetic elements for the whole of France.

A comparison of the errors in the various elements with the geological character of the soil at the several stations of the survey seems to afford no indication of any decided disturbance due to igneous or other formations. The errors appear rather to arise from accidental causes, such as unknown masses of iron in the vicinity of the station of observation, imperfection of instruments, &c.; I have therefore omitted the geological Table.

Neither do I think it necessary to join to this paper maps of the Isoclinals, Isogonics, and Isodynamics, as those for the west of France sufficiently indicate the general lie of the lines.

It may not perhaps be thought superfluous if I add to this report, in the form of an Appendix, the observations and equations of conditions which have been deduced from LAMONT's data, in order to compare the survey of 1858 with that discussed in the preceding pages.

It will also be well to remark that some of the results given in this paper for the west of France differ a little from those already published. This arises from the observations having been reduced afresh by a slightly different and more accurate method, similar in every respect to that used for the east of France, and in the discussion of all LAMONT's observations.

Before concluding this paper I must express the great obligations I am under to the

Rev. J. HAWETT, S.J., without whose assistance in reducing and verifying the results I should have been forced to delay the presentation of these pages for a very considerable time.

APPENDIX.

In order to determine with greater exactness the secular variations of the Isoclinals, Isodynamics, and Isogonics, the values for 1858 have been calculated from LAMONT'S data by the same process as that adopted for the survey of 1868 and 1869. The data taken from Dr. LAMONT'S 'Untersuchungen über die Richtung und Stärke des Erdmagnetismus' are contained in the following Table.

TABLE XXI.

Station.	Latitude.	Longitude.	Dip.	H. F.	Declination.
	° ′ ″	m s	° ′		° ′
Agen	44 12 48	6 53	63 21·6	2·0491	19 15·1
Amiens	49 53 24	0 4	....	1·8277	19 56·3
Angers	47 28 2	11 37	65 55·9	1·9112	20 16·3
Angoulème	45 38 34	8 45	64 39·1	1·9899	19 50·2
Arras	50 16 47	1 46	67 23·2	1·8201	
Bayonne	43 29 12	15 19	63 6·8	2·0691	19 57·8
Belfort	47 37 37	18 1	....	1·9545	17 11·7
Bordeaux	44 50 13	11 27	64 5·8	2·0163	20 0·2
Brioude	45 18 0	4 12	63 44·3	2·0321	18 21·9
Cette	43 24 36	5 24	....	2·1173	17 7·9
Chateauroux	46 48 14	2 31	65 6·9	1·9527	19 22·0
[illegible]	45 46 22	3 0	64 12·1	2·0068	18 34·1
Commercy	48 45 54	13 1	....	1·9044	
Dijon	47 19 53	10 46	64 55·0	1·9543	17 55·9
Dunkirk	51 1 33	0 5	67 56·3	1·7871	20 6·6
Epernay	49 2 52	6 27	66 35·6	1·8790	
Etampes	48 26 8	0 41	66 16·0	1·8886	
Lamothe	44 37 24	13 22	63 57·1	2·0235	
La Roche Chalais	45 9 39	9 25	....	2·0064	19 46·3
La teste de Buch	44 38 11	13 57	63 59·8	2·0222	20 3·9
Le Mans	47 59 34	8 39	66 13·0	1·8903	20 25·7
Le Puy	45 2 46	6 12	....	2·0473	
Limoges	45 50 3	4 21	....	1·9870	19 23·8
Marseilles	43 17 45	12 15	61 40·5	2·1363	17 4·1
Meaux	48 57 2	2 11	66 24·2	1·8765	19 16·4
Mont de Marson	43 53 18	11 19	63 19·0	2·0557	19 40·3
Montélimart	44 33 18	9 36	62 53·3	2·0750	17 35·5
Montpellier	43 36 44	6 10	62 15·3	2·1112	
Moulins sur Allier	46 34 24	3 56	64 43·4	1·9758	18 39·2
Nancy	48 41 17	15 19	....	1·8985	17 45·6
Nantes	47 12 24	15 35	65 55·9	1·9096	20 57·8
Narbonne	43 11 8	2 38	62 6·4	2·1184	18 1·1
Orange	44 8 42	9 52	62 36·9	2·0931	17 27·7
Orleans	47 54 9	1 42	65 52·6	1·9079	19 25·4
Paris	48 50 13	0 0	66 26·5	1·8759	19 36·3
Périgueux	45 10 32	6 29	....	2·0149	19 26·5
Perpignan	42 42 9	2 15	61 47·8	2·1357	17 59·2
Poitiers	46 34 31	7 58	65 8·3	1·9523	19 56·4
Sarrebourg	48 43 57	18 53	....	1·8989	17 14·6
Toulouse	43 36 33	3 35	62 46·1	2·0861	18 45·0
Tournon	45 3 57	10 1	63 18·2	2·0543	17 40·9
Tours	47 23 5	6 36	65 44·3	1·9192	19 54·4
Vésoul	47 37 3	15 14	....	1·9496	17 28·8

The Horizontal Force is expressed above in the French units of the millimetre, the milligram, and the second of mean solar time. Its value is found from the formula

$(\text{H. F.})^2 = \frac{2\pi^2 \text{K}}{\text{T}^2 r^3 \sin u}$, where K, the moment of inertia of the magnet, is equal to $\text{W}\left(\frac{l^2}{12}+\frac{d^2}{16}\right)\frac{t^2}{t'^2-t^2}$, l, d, and r being distances. Hence, in order to transform the values of H. F. so that they may be expressed in the English units of a foot, a grain, and a second, we have only to multiply by the square root of the factor of mass, and to divide by the square root of the factor of distance, whose quotient is 2·1688. Effecting this transformation, and choosing for our coordinates the meridian of Paris, and a perpendicular to that meridian, the origin of coordinates being the Imperial Observatory, we obtain the equations of condition for determining the lines of equal Dip, Declination, and Intensity. As the second members of the equations are the same for the different elements, I will include in a single Table the first members of each set of equations, followed by the second members for the several stations.

TABLE XXII.

Station.	Dip.	Declination.	H. F.	T. F.	Second members.
Agen	° 2·360	° 2·252	1·4441	0·9111	$=z+85{\cdot}45x+319{\cdot}30y$
Amiens	....	2·938	0·9639	....	$=z+0{\cdot}74x-72{\cdot}80y$
Angers	4·932	3·272	1·1450	1·1637	$=z+136{\cdot}03x+94{\cdot}59y$
Angoulême	3·652	2·837	1·3157	1·0806	$=z+105{\cdot}96x+220{\cdot}60y$
Arras	6·387	....	0·9474	1·2661	$=z-19{\cdot}56x-99{\cdot}74y$
Bayonne	2·113	2·963	1·4875	0·9230	$=z+192{\cdot}46x+369{\cdot}46y$
Belfort	....	0·195	1·2389	....	$=z-210{\cdot}34x+83{\cdot}56y$
Bordeaux	3·097	3·003	1·3730	1·0101	$=z+140{\cdot}63x+276{\cdot}24y$
Brioude	2·738	1·365	1·4072	0·9605	$=z-51{\cdot}17x+244{\cdot}23y$
Cette	....	0·132	1·5920	....	$=z-67{\cdot}94x+374{\cdot}75y$
Chateauroux	4·115	2·367	1·2350	1·0642	$=z+29{\cdot}84x+140{\cdot}41y$
Clermont Ferrand	3·202	1·568	1·3523	1·0007	$=z-36{\cdot}24x+211{\cdot}62y$
Commercy	....	....	1·1303	....	$=z-148{\cdot}63x+4{\cdot}93y$
Dijon	3·917	0·932	1·2385	0·9979	$=z-126{\cdot}40x+103{\cdot}60y$
Dunkirk	6·938	3·110	0·8759	1·3190	$=z-0{\cdot}91x-151{\cdot}31y$
Epernay	5·593	....	1·0752	1·2583	$=z-73{\cdot}24x-14{\cdot}61y$
Etampes	5·267	....	1·0960	1·1769	$=z+7{\cdot}85x+27{\cdot}69y$
Lamothe	2·952	....	1·3886	0·9838	$=z+164{\cdot}77x+290{\cdot}99y$
La Roche Chalais	....	2·772	1·3515	....	$=z+115{\cdot}00x+255{\cdot}01y$
La teste de Buch	2·997	3·065	1·3857	1·0035	$=z+171{\cdot}92x+290{\cdot}09y$
Le Mans	5·217	3·428	1·0997	1·1659	$=z+100{\cdot}28x+58{\cdot}28y$
Le Puy	....	....	1·4402	....	$=z-75{\cdot}87x+261{\cdot}80y$
Limoges	....	2·397	1·3094	....	$=z+52{\cdot}50x+207{\cdot}38y$
Marseilles	0·675	0·068	1·6332	0·7649	$=z-154{\cdot}40x+382{\cdot}63y$
Meaux	5·403	2·273	1·0698	1·1669	$=z-24{\cdot}84x-7{\cdot}89y$
Mont de Marsan	2·317	2·672	1·4584	0·9283	$=z+141{\cdot}25x+341{\cdot}73y$
Montélimart	1·888	0·592	1·5003	0·8749	$=z-118{\cdot}48x+295{\cdot}57y$
Montpellier	1·255	....	1·5788	0·8355	$=z-77{\cdot}32x+360{\cdot}79y$
Moulins sur Allier	3·723	1·653	1·2851	1·0356	$=z-46{\cdot}84x+156{\cdot}33y$
Nancy	....	0·760	1·1175	....	$=z-175{\cdot}17x+10{\cdot}25y$
Nantes	4·932	3·963	1·1415	1·1552	$=z+183{\cdot}96x+113{\cdot}74y$
Narbonne	1·107	1·018	1·5944	0·8207	$=z-33{\cdot}25x+390{\cdot}25y$
Orange	1·615	0·462	1·5395	0·8692	$=z-122{\cdot}62x+325{\cdot}17y$
Orleans	4·877	2·423	1·1379	1·1244	$=z+19{\cdot}74x+64{\cdot}52y$
Périgueux	....	2·442	1·3699	....	$=z+79{\cdot}18x+253{\cdot}90y$
Perpignan	0·797	0·987	1·6319	0·8009	$=z-28{\cdot}63x+423{\cdot}97y$
Poitiers	4·138	2·940	1·2341	1·0710	$=z+94{\cdot}86x+157{\cdot}35y$
Sarrebourg	....	0·243	1·1183	....	$=z-215{\cdot}77x+7{\cdot}18y$
Toulouse	1·768	1·750	1·5243	0·8873	$=z+44{\cdot}93x+360{\cdot}98y$
Tournon	2·303	0·682	1·4554	0·9170	$=z-122{\cdot}53x+260{\cdot}44y$
Tours	4·738	2·907	1·1624	1·1298	$=z+77{\cdot}41x+100{\cdot}29y$
Vésoul	....	0·480	1·2283	....	$=z-177{\cdot}88x+84{\cdot}21y$

III. *On the Structure and Affinities of* Guynia annulata, *Dunc., with Remarks upon the Persistence of Palæozoic Types of Madreporaria. By* P. MARTIN DUNCAN, *M.B. Lond., F.R.S., Professor of Geology in King's College, London.*

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I. DURING their comprehensive study of the Fossil Corals of the Palæozoic rocks, MM. MILNE-EDWARDS and JULES HAIME were impressed with the necessity of founding the great section of the Madreporaria called the Rugosa; they established the section in 1850*, and confirmed its differentiation in 1860†. The characters of the Rugosa were then decided to be as follows:—"In this division, which comprehends simple as well as compound corals, the septal structures never form six distinct systems . . . and appear to be referable to four primitive elements. Sometimes this arrangement is evidenced by the great development of four principal septa, or by the existence of a corresponding number of depressions which are seen at the bottom of the calicular fossa and which give a crucial appearance to it. In other instances one depression or one large septum exists so as to interrupt the perfection of the septal star. Occasionally no groupings or systems can be distinguished; and the septa are represented by striations which rise up on the upper surface of the tabulæ, or by endothecal vesicles which may be observed on the inner side of the wall. The corallites are always distinct and separate from each other, for they are never united by an independent cœnenchyma. The wall is usually feebly developed. The visceral chamber is usually occupied by a series of tabulæ, or by vesicular endotheca, which often constitutes the bulk of the corallum. The septa, although often incomplete, are never porous or spongy, and they are rarely granular, and never have synapticulæ attached to their laminæ. The individual corallites multiply by gemmation, and do not undergo fissiparous division. The reproductive buds usually

* Monograph of the British Fossil Corals. London, 1850, Palæontographical Society.

† Histoire Naturelle des Coralliaires. Paris, 1860.

grow upon the calice of the parent, whose growth they arrest, and thus a superposition of generations is induced. In some genera the gemmation is lateral."

This section of the Madreporaria necessarily included a great number of genera; and as they all could be readily distinguished from those of the other great sections, the new arrangement was adopted by palæontologists.

It was all the more acceptable because the predominant idea of the geologists of those days was favoured by the assertion of the existence of any definite groups of organisms which were characteristic of and peculiar to certain geological formations. The Palæozoic series of rocks was supposed to contain the fossil remains of a fauna and flora which became extinct before the deposition of the Triassic sediments took place, and a great break in the continuity of life on the earth was believed to have happened. Every generalization which appeared to favour such hypotheses was usually accepted as correct without being subjected to searching criticism; and consequently the foundation of the section Rugosa, in contradistinction to those of the Aporosa and Perforata, was supposed to necessitate the inference that the Palæozoic Madreporaria differed most essentially from the Neozoic.

Thus the distinguished author of 'Siluria' writes:—" One of the most important of these discoveries, resulting from the labours of Professor MILNE-EDWARDS, and his coadjutor, M. JULES HAIME, appears to be, that the majority, if not all, of the corals of the Silurian system, and indeed of the whole Palæozoic era, belong to divisions of the coral tribe unknown in modern seas: with rare exceptions, these groups became extinct at the close of the Palæozoic epoch. If this be established, and the large cup- and star-corals (Zoantharia rugosa) and the massive Millepores (Z. tabulata) be, as a whole, distinct in structure from the star-corals and Madrepores of the Secondary and Tertiary rocks and of existing coral-reefs, we gain a new fact in the history of animal life upon the globe, which is in harmony with results obtained by the study of the Crustacea, Mollusca, and Fish of the older epochs" ('Siluria,' 4th edition, 1867, p. 217). Moreover, in a note to page 220 of the same work, the restriction of the non-rugose corals to the Mesozoic and Cainozoic periods is inferred.

Although the Zoantharia tabulata are as numerous in the existing coral-faunas as they were in the Palæozoic (and some of the genera are closely allied), the presumed fact of the restriction of the Rugosa to the Palæozoic formations tempted many to come to the erroneous conclusion respecting the break in the continuity of coral life at the end of the Permian age.

The characteristic nature of the Palæozoic coral-fauna was, moreover, strengthened in the minds of some by the able manner in which MM. MILNE-EDWARDS and JULES HAIME overthrew the old classification of the corals of the Muschelkalk and St. Cassian strata of the Trias, and proved that they were not of Palæozoic genera. Strengthened by the opinions of many geologists respecting the limitation of life, a number of able palæontologists have persisted in refusing credence to any facts which should prove, if they were no longer called anomalies, that the Rugosa were not restricted to the Palæozoic

age, and that there has not been a break in the succession of coral species by descent since the first of them appeared in the seas of old. If the supporters of the hypothesis which restricts the Rugosa to the Palæozoic rocks had studied the great work of the distinguished French zoophytologists so often mentioned by me, they would have found that the following words occur therein:—" Le groupe des Zoanthaires rugeux . . . se compose presqu'entièrement d'espèces fossiles appartenant aux terrains anciens"*. The exception alluded to was a most remarkable and striking one, which was well known to every geologist of note. LONSDALE† had described a common fossil which was discovered by FITTON in the Lower Greensand of Atherfield: it was a coral with rugose characteristics, and MM. MILNE-EDWARDS and JULES HAIME placed it amongst the Rugosa and named it *Holocystis elegans*, Lonsdale, sp. The specimens are abundant, and they evidently grew and lived in the Neocomian seas. The existence of the species was considered to have been anomalous; but it excited much attention amongst those palæontologists who were disposed to consider such anomalies as broken links in a great chain of evidence. Any forms which might connect the Neocomian species with the Palæozoic were eagerly sought for, but without success; and the distinctness of the Palæozoic and Neozoic coral-faunas (excepting the Zoantharia tabulata, about which much may be said) might still be generally admitted, had not the results of the explorations of the sea-floor by the Americans and by the naturalists of the 'Porcupine' expeditions reopened the question.

Count POURTALES‡ found a coral with rugose characteristics amongst the dredgings which were obtained from off the floor of the sea, five miles distant from the Florida reef, in 1868; he founded a new genus to receive the interesting form, and described it specifically as *Haplophyllia paradoxa*, Pourtales. Fortunately the living tissues were examined and described.

Within the present year (1871) I have examined numerous specimens of a coral which is new to science, and which presents most marked rugose peculiarities. The specimens were dredged up in the last expedition of the 'Porcupine' from off the Adventure Bank in the Mediterranean§, and their description forms the most important part of this communication.

The presence of two genera of Rugosa in the existing coral-fauna has led me to examine the rugose peculiarities of several species of the genus *Conosmilia* which were described by me in an essay on the Fossil Corals of the Australian Tertiary Deposits‖, and also to reconsider the evidence offered respecting the descent of many Lower Liassic corals from Palæozoic Rugosa, and which was published in 1867¶.

With a view to connect this evidence with the results of the reconsideration of the Australian species just alluded to and the discovery of the recent Rugosa, I have intro-

* Hist. Nat. des Corall. vol. iii. p. 324.

† Quart. Journ. Geol. Soc. vol. v. 1849.

‡ Contributions to the Fauna of the Gulf-stream at great depths, 2nd series, 1868 (L. F. POURTALES).

§ CARPENTER and JEFFREYS "On Deep-sea Researches," Proc. Royal Soc. vol. xix. pp. 175, 176.

‖ Ann. & Mag. Nat. Hist. September 1865, and Quart. Journ. Geol. Soc. February 9, 1870.

¶ Brit. Foss. Corals, Supplement issued for 1867. Palæontographical Society, London.

duced in this paper a notice of the species of the Secondary rocks which were known to depart from the usual hexameral type, and which were described by MM. MILNE-EDWARDS and JULES HAIME* and by M. DE FROMENTEL†. This course of proceeding is necessary in order to show how the rugose type has persisted during the Neozoic ages.

II. Genus GUYNIA.

The corallum is simple and long. The wall is thick and solid. The septa are well developed, lamellar, unequal, and are continuous from the base to the calice. There are four systems of septa, and one primary septum is longer and larger than the others. The columella is essential, and is attached to the larger septa. There is no endotheca. The costæ are visible on the growth-rings of the outside of the wall. There is an epitheca.

Species *Guynia annulata*, sp. nov. Plate I. figs. 1–8.

The corallum is long, cylindrical, and narrow; it is sometimes curved. The accretion-ridges are well developed and regular, and are marked with prominent short spinules, laminæ, or granules which correspond with the costæ. The epitheca ornaments the ridges, and is delicate. The costæ extend over the whole length of the corallum, and usually exist as flat bands between the close and rather wavy accretion-ridges.

There are four principal septa, one of which is larger than the others at the calice. The four secondary septa are often as large as the primary, but the eight tertiary septa are almost rudimentary. There are four systems of septa, and three cycles in each; none are exsert. The columella is stout, cylindrical, deeply seated in the calice, and adherent to the larger septa. The interseptal loculi are large, and the transverse outline of the corallum is sometimes rather angular. The length of the perfect corallum probably $\frac{3}{4}$ inch, the breadth $\frac{1}{20}$ inch.

Locality. Adventure Bank in 92 fathoms.

The numerous specimens of this coral are in excellent preservation, and their condition is that of living forms whose soft parts have been crushed or washed out during the operation of removal from their usual locality. Many of the corals adhered by their sides to mollusca, and resembled annelid-tubes marked with a regular series of ring-like accretion-ridges.

III. The numerous growth-rings or accretion-ridges give the species a very palæozoic facies, especially when there is a very decided constriction between two annular prominences: this facies is made more decided when the tetrameral arrangement or type of the septa is noticed and the solid columella is distinguished. The stout wall and the absence of endotheca are exceptional peculiarities; but although they are not mentioned in the diagnosis of the Rugosa by MM. MILNE-EDWARDS and JULES HAIME, they are admitted as characterizing a most important family of them—the *Cyathaxonidæ*.

* Hist. Nat. des Coralliaires, 1860.

† E. DE FROMENTEL, 'Polypiers fossiles,' 1858–61.

The following is the diagnosis of the *Cyathaxonidæ*, the second family of the section Rugosa*:—

"Corallum having a well-developed septal apparatus, the laminæ extending uninterruptedly from the base to the summit of the visceral chamber, and leaving open fossulæ between them without dissepiments, tabulæ, or synapticulæ. The primary septa are not decidedly more developed than the others, and do not form a cross as in most of the Stauridæ."

Up to the present time but one genus has been associated with this family, viz. *Cyathaxonia*, Michelin†; it is thus described by MM. Milne-Edwards and Jules Haime‡:—

"The corallum is simple, free, finely pedicellate, and has the shape of an elongate and curved cone. There is a complete epitheca. There is a well-developed septal fossula situated on the side of the great curvature. The columella is styliform and very projecting. The septa are smooth and numerous, and most of them unite with the columella."

The accretion-ridges and wall are particularly well marked in *Cyathaxonia tortuosa*, Michelin, and the size of the septal fossula varies with the species. The genus was represented in the Upper-Silurian strata of Gothland, and perhaps in the Ludlow rocks of England, but its species have not been found in Devonian strata: nevertheless it is not a rare fossil genus in the American and Belgian Carboniferous strata. *Cyathaxonia cornu*, Michelin, is said to be found in English and Belgian Carboniferous deposits.

The great distinction between *Guynia* and *Cyathaxonia* is the absence of the septal fossula in the first genus; but its species has a large septum, which is a very marked rugose peculiarity, and the replacement of such septa by depressions or fossulæ is common.

There is therefore no reason why *Guynia annulata* should not be placed in the family of the *Cyathaxonidæ*, and that its genus should not be closely associated with *Cyathaxonia*§.

IV. Count Pourtales describes the genus *Haplophyllia* (Plate I. figs. 13–15) as follows‖:—

"Corallum simple, fixed by a broad base, covered with a thick epitheca; columella styliform, strong, very thick at the base. Interseptal chambers deep, uninterrupted by tabulæ or dissepiments, but filling up solid at the bottom."

An introductory paragraph¶ supplies the defective information respecting the septal apparatus. He therein states:—"The singular coral next to be described strikes one at first sight by its resemblance to some of the members of the group of the Rugosa of Milne-Edwards and Haime. A closer examination tends to confirm that view, much as it seems improbable to find a living representative of a group so long extinct. In no other division of the corals is the septal apparatus subdivided into systems that are multiples of four; but such is the case in our specimen, though a little obscured by acci-

* Hist. Nat. des Corall. vol. iii. p. 329.

† Icon. Zooph. 1846.

‡ *Op. cit.* p. 329.

§ I have named the genus after Mr. Gwyn Jeffreys, F.R.S.

‖ *Op. cit.* p. 140.

¶ Pages 139 and 140.

dental causes. Another, though perhaps less important, character is the smoothness of the septa, which present neither perforations, nor synapticula, nor granulations. Tabulæ, however, there are none, the interseptal characters being open from top to bottom. Among the Rugosa this character is only found in the family of the *Cyathaxonidæ*, to or near which, therefore, our coral must find its place. From the genus *Cyathaxonia* it differs in being attached by a broad base, and also by the absence of a septal fossula."

Haplophyllia paradoxa, Pourtales.

"Corallum subcylindrical, short, fixed by a broad base; epitheca thick, wrinkled, reaching higher than the calice, and forming around it several concentric circles as if representing the separated borders of several superposed layers. Calice circular, fossa deep. Septa smooth, without granulations or perforations, not reaching the border of the calice; like all the internal parts of the calice, their surface is like enamel. Columella composed of two smooth conical processes, very thick at the base and tending to fill up the chambers. Eight septa, larger and connected with the columella, alternating with smaller ones which touch the columella at a much lower level. A further cycle is indicated by small ridges of the wall-surface in some of the chambers. No distinction can be made between primary and secondary septa among the eight larger ones, as they all appear equal.

"Height about ½ inch; diameter of the calice ½ inch.

"The coral was living when obtained; the polyp was of a greenish colour, but was not otherwise examined when fresh. After having been in alcohol it could be lifted out entire from the calice, presenting an exact cast of the chambers. The mouth is surrounded by a circle of about sixteen rather long tentacles, bluntly tuberculated at the tip. Outside the circle of tentacles extends a membranous disk with radiating and concentric folds."

This unique specimen was dredged up in 324 fathoms off the Florida reef.

It is evident that this interesting form and that which was dredged off the Adventure Bank have much in common. Both must be classified amongst the *Cyathaxonidæ*; and it is quite possible that future dredgings may discover intermediate forms which will necessitate the absorption either of the genus *Haplophyllia* or of *Guynia*. At present the shape of the closely allied forms, their septal number, the nature of the columellæ, and the characters of the epithecal structures must be considered to separate them generically. The large septum, so visible in some of the specimens of *Guynia annulata*, constitutes in itself a differentiation.

Admitting the generic alliance to be of the closest, *Guynia* and *Haplophyllia* will form with *Cyathaxonia* the three genera of the family *Cyathaxonidæ* of the section Rugosa.

V. In describing some fossil corals from the Miocene deposits of Australia in 1865, I noticed some species of a new genus in the following manner *:—" The new genus *Conos-*

* Ann. Mag. Nat. Hist. 1865, xvi. p. 185.

milia possesses the twisted ribbon-shaped columella of the subfamily *Caryophyllaceæ*, the endotheca and septal margin of the *Trochosmiliaceæ*, and the irregular septal arrangement which was so common in the corals of the Oolitic age, and which, from its octomeral type, reflected the Rugosa of Palæozoic times."

The Geological Survey of Victoria sent me a great number of Miocene corals for examination and description, and the species were figured and described in an essay on the Fossil Corals of the Australian Tertiary Deposits, read before the Geological Society, February 9, 1870. The four well-marked species of the genus *Conosmilia* were examined and reconsidered; but I could not separate them naturally into two groups, although three out of the four had the octomeral septal arrangement; the fourth had the usual Neozoic hexameral type of septal apparatus. I wrote as follows*:—"The most interesting of the corals from the Cainozoic deposits of South Australia are the *Conosmiliæ*. It is a genus perfectly Australian in its abnormalities. A simple coral with a pellicular epitheca, having a beautiful herring-bone ornamentation, with an essential, twisted, "sérialaire" columella with endothecal dissepiments, and with plain septa, which have the hexameral arrangement in some and the octomeral in others, is a form containing the elements of several classificatory series. The irregular septal arrangement amongst the closely allied species may be considered to depend upon atavism. Such octomeral cyclical arrangements occurred in some genera in the Lower-Greensand period and during the Oolites, &c."

When the rugose peculiarities of three out of the four species of this genus are considered in relation with the discoveries of existing corals belonging to the section Rugosa the opinion that they were due to recurrence to ancestral types may well be modified. Like *Haplophyllia* and *Guynia* the *Conosmiliæ* did not belong to a reef-fauna, but to those deep-sea faunas which contain so many persistent types. If the theory that the *Conosmiliæ* were originally of an hexameral septal type is correct, then the three out of the four known species have departed from it and reflect the peculiarities of the ancient Rugosa; but if it be admitted that the genus belonged originally to the tetrameral or octomeral type (for they are identical), then these three Miocene forms were direct descendants of the Palæozoic Rugosa, and the one hexameral species was a modification. Whichever theory is accepted, the descent from a Palæozoic type is inferred. There is an interesting relation between so many recent Australian animals and plants and those of the late Palæozoic and early Neozoic ages, that, believing in the possibility of the persistence of coral types belonging to those remote times, I have investigated the structures of the *Conosmiliæ* with a view of associating three of the species with the Rugosa. The result is somewhat remarkable; for it indicates that if the *Conosmiliæ* can be regarded as *Rugosa*, they must be placed amongst the *Stauridæ*, in the neighbourhood of the genus *Polycœlia*, whose species are of Permian age in Europe.

Conosmilia elegans, Dunc., *Conosmilia lituolus*, Dunc., and *Conosmilia anomala*, Dunc., have, in addition to the rugose septal arrangement, an endotheca which closes off the

* Quart. Journ. Geol. Soc. vol. xxvi. p. 309.

lower portions of the interseptal loculi; but it is curved and arched, and is dissepimental rather than horizontal and tabulate. Their fasciculate columellæ and faint pellicular epithecas are remarkable structures; and their costal arrangement, by which the septum corresponds with the intercostal space, is eminently characteristic of some Rugosa.

They differ from the *Cyathaxonidæ* in having an endotheca; but their completely lamellar septa and their distinct costæ associate them with the next, or rather the first family of the Rugosa—the *Stauridæ*.

The *Stauridæ* were formed into a family by MM. MILNE-EDWARDS and JULES HAIME in 1850 *, and it was differentiated as follows:—

The septa are well developed, and are formed of perfect laminæ, which extend uninterruptedly through the length of the visceral chamber; they are united laterally by lamellary cross dissepiments, and they are arranged in four systems, usually characterized by the presence of four large septa arranged in the shape of a cross. The wall is well developed and imperforate.

The family contained in 1850 two genera of compound and two of simple corals.

The first are, of course, out of the line of the present communication, except that one of them, the *Holocystis* of the Lower Greensand, offers a remarkable proof of the persistence of the rugose type.

The second or simple coral genera are *Polycœlia* and *Metriophyllum*.

Polycœlia has no columella, and the dissepimental tissue is in the form of horizontal tabulæ, and in *Metriophyllum* the septa are grouped in four fasciculi. Had a species of *Polycœlia* a fasciculate columella and a few arched dissepiments, it would represent one of the *Conosmiliæ* with the tetrameral type—the *Conosmilia lituolus* for instance.

The manner in which curved or arched dissepiments are associated with and follow tabulæ in the same rugose corals may be seen in many specimens of Carboniferous species, so that the distinction between the two conditions is not so great as was thought formerly. The absence of a columella is a generic distinction.

Conosmilia, according to the theory of its being a persistent type, should be admitted into the *Stauridæ*, in the neighbourhood of the genus *Polycœlia*.

MM. MILNE-EDWARDS and JULES HAIME classify the *Stauridæ* as the first family of the Rugosa, and the *Cyathaxonidæ* as the second; and the distinction is the want of endothecal structures in the last-named natural division.

VI. If the occurrence of a tetrameral septal arrangement in a Miocene genus in which there is a species with the normal Neozoic hexameral type has any significance with reference to older forms, corresponding phenomena should be more common in more ancient faunas,—that is to say, the secondary strata should contain a greater number of tetrameral and octomeral types combined with the hexameral than the tertiary deposits; the fossil corals of the oldest secondary rocks should retain greater evidences of it from Palæozoic Rugosa than those of a later date.

The following data may be advanced in proof of the occurrence of these requirements.

* *Op. cit.* vol. iii. page 324.

The discovery of the rugose *Holocystis elegans*, Lonsd. sp., in the Necomian has already been noticed; it is a species which belongs to the same family as *Stauria* and *Conosmilia*.

M. DE FROMENTEL has arranged many genera of Secondary and Tertiary corals according to their septal types; and he notices that a doubtful generic title is given to *Dimorphocœnia corallina* by ETALLON, and that the form which belongs to the Middle Oolite coral-fauna is one of the Rugosa. The other species of the genus, and which is the type of it, has the hexameral septal arrangement, and is a Neocomian fossil.

The same author notices and describes *Pleurostylina corallina* from the Middle Oolite, and proves that, with the normal Neozoic hexameral septal type, it has a relic of the rugose structure in a large septum which passes into the axial space.

Stephanocœnia is a genus with existing Lower Cretaceous and Middle Oolite species having the hexameral septal type; but there are other species found in the Eocene and in the Lower Chalk which have the octomeral arrangement.

Stylocœnia has species with a pentameral type in the Eocene and Lower Cretaceous deposits, and some with the octomeral septal arrangement in Eocene and Miocene strata*.

Stylina has species with the hexameral arrangement in the Upper, Middle, and Inferior Oolites, and others with the octomeral in the Middle Oolite and Lower Chalk; moreover it has species in the Trias and Middle and Inferior Oolites which have the decameral septal type.

Cryptocœnia has hexameral types in the Neocomian and in the Middle and Inferior Oolites; but the Middle and Inferior Oolitic strata contain species of it with the octomeral septal arrangement.

Goniocora affords examples of hexameral species in the Upper and Middle Oolites and in the Lias, whilst there is an octomeral type in the Middle Oolitic rocks.

Astrocœnia has hexameral species in the Eocene and Neocomian deposits, octomeral in the Lower Cretaceous and Middle and Upper Oolitic strata, and in the Tertiaries of Castel Gomberto†; but all the species described by me from the lowest Liassic strata possess the decameral type. The lowest coralliferous secondary deposits of Great Britain contain badly preserved fossils, and yet the Thecosmilian from the White Lias of Watchet and the cast of a congeneric form from that of Sparkfield have very rugose characters‡. The *Thecosmiliæ* from the "Guinea bed" at Binton (zone of *Ammonites planorbis*) have the great septum and thin wall of many Rugosa§; and the species of *Oppelismilia* from the next and higher zone of *Ammonites angulatus* has no distinct septal arrangement, but a thick epitheca and calicular gemmation. The great Astrocœnian fauna of the zone is composed of twelve species, all of which have the decameral septal arrangement, and none of them the hexameral. Many of the *Montlivaltiæ* of the zone are so irregular in their development that they cannot be classified under any

* REUSS, Castel Gomberto, Foss. Anthoz. Kaiser. Akad. der Wissen. Wien, 1868.

† REUSS, *op. cit.*

‡ P. M. DUNCAN, Pal. Soc. Lond. vol. xxi. p. 67.

§ Id. p. 66.

type; others have the hexameral arrangement, and *Montlivaltia Murchisoniæ*, Dunc., has its septa collected together in four systems. All the species have epitheccate walls.

In the zone of *Ammonites Bucklandi* the genus *Lepidophyllia* has a very rugose facies; and *Montlivaltia radiata*, Dunc., of the zone of *Ammonites raricostatus*, is evidently furnished with a septal arrangement on the tetrameral type, the four principal septa being very large. Even in the Middle Lias, *Lepidophyllia hebridensis*, Dunc., has a rugose aspect; and the greatest of all *Montlivaltiæ*, the *Montlivaltia Victoriæ*, of the zone of *Ammonites Henleyi*, has an epitheccate wall, although there are six systems of septa.

Thus from the Rhætic beds to the Middle Liassic strata the examples of more or less modified rugose types are frequent; for the species with the decameral septal arrangement very probably originated from forms of Rugosa with indefinite septal numbers. After the age of the Lias to the Tertiary period the septal arrangements of many species and subgenera appear to be very confused; but still many rugose types persisted, having the tetrameral disposition or the decameral; so that if it is admitted (and it may be so consistently with exact truth) that some of the Triassic corals, especially the *Montlivaltiæ*, have certain but rather faint rugose characters, there is evidence that there has not been a marked break in the continuity of coral life.

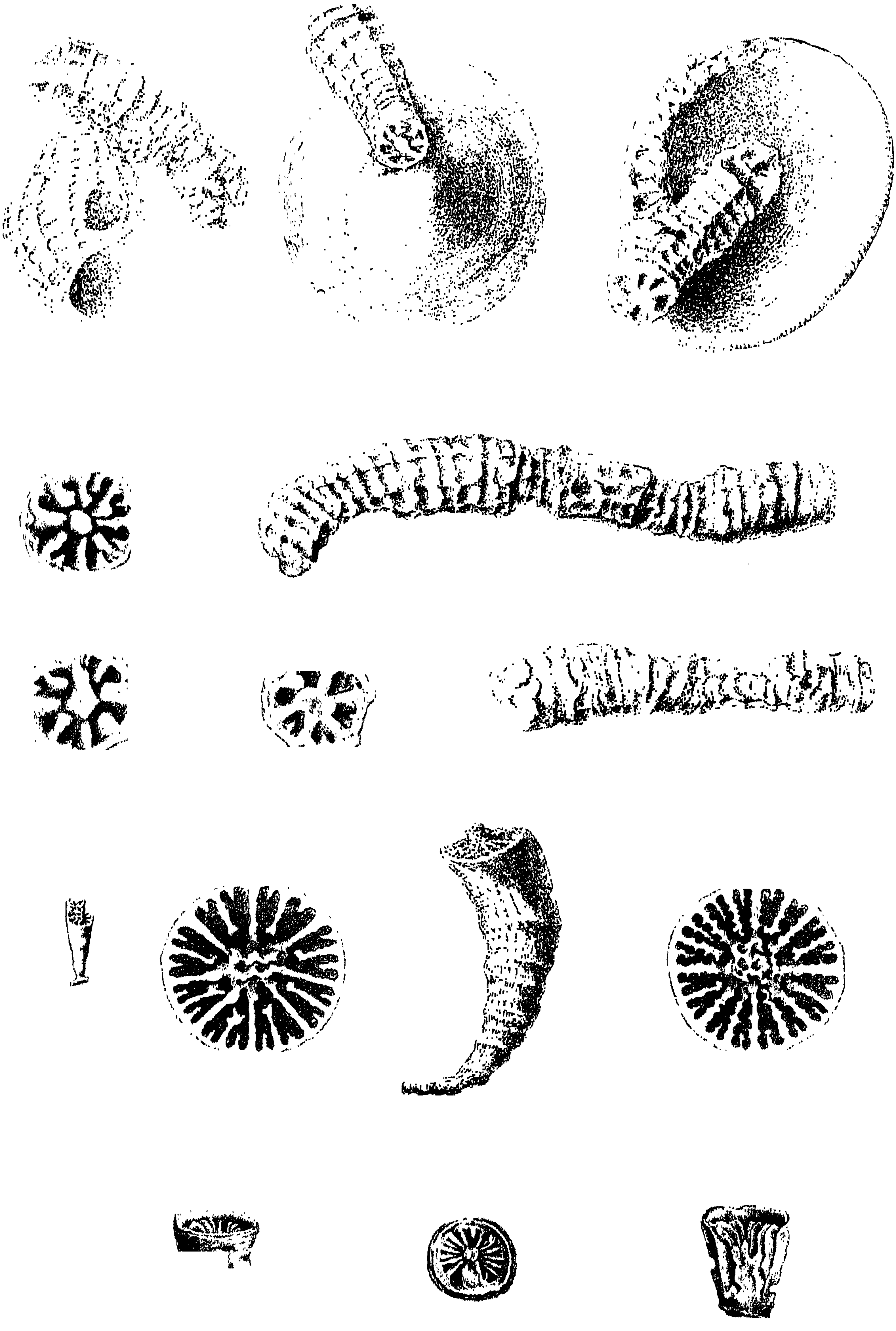
Doubtless many species have varied and have recurred to their ancestral forms; and this may account for the appearance of tetrameral or octomeral types late in the world's history in genera whose older secondary species were of the hexameral type; but the persistence of the rugose type, more or less modified, up to the present day can no longer be denied.

Probably many genera with hexameral septal arrangements originated in Palæozoic times; and I have noticed in a former communication* the interesting relation of the Carboniferous *Heterophylliæ* and the Devonian *Battersbyiæ* to the corals of the normal Neozoic type.

VII. It is very remarkable that the two recent species of Rugosa, *Haplophyllia paradoxa*, Pourtales, and *Guynia annulata*, Duncan, should belong to the same family of the section, and that the tertiary *Conosmiliæ* with Palæozoic affinities should of necessity be included in a closely allied family of the Rugosa.

That the American and Mediterranean species should be closely allied is in keeping with the results of the study of the distribution of deep-sea as well as of shallow-water forms in those distant localities. The Hippurite limestones of Jamaica contain the same species of Madreporaria as the Cretaceous rocks of Gosau in Austria; the dark Eocene shales of the same island have yielded the same species of Madreporaria as the early Tertiary deposits of North-western Europe; the Miocene fauna of the Caribbean islands contains the characteristic species of the corresponding Falunian deposits of France, Italy, and Malta; and even the recent Algæ of part of the West-Indian area resemble those

* Philosophical Transactions, 1867, p. 643.



of the Mediterranean. As regards the Radiata and the Foraminifera, there has been a very prolonged correspondence of identical and representative species between the distant areas, and now the occurrence of closely allied species belonging to the persistent rugose type attests still further the interesting biological relations between the two margins of the great Atlantic.

It has been noticed that the *Conosmiliæ* of the old Australian seas, now found included in Midtertiary deposits along the northern shores of Victoria and South Australia, belong to the Stauridæ, and that their close ally in that rugose family is the genus *Polycœlia*. This genus is extinct, and formed the characteristic coral-fauna of the very uncoralliferous Permian deposits. Considering the well-known Triassic, Jurassic, and, indeed, the Palæozoic facies of portions of the recent and tertiary Australian faunas, the establishment of the *Conosmiliæ* with their Permian affinities as part of a family of the Rugosa is highly suggestive.

In conclusion, I think that there can be no doubt about the persistence of the rugose type of Palæozoic Madreporaria through the Neozoic formations to the present time, and that the species with hexameral and decameral septal arrangements descended from rugose types, and the latter especially from those with an indefinite septal number.

VIII. Explanation of the Plate.

PLATE I.

Fig. 1. Portion of the corallum of *Guynia annulata* fixed to a shell. Magnified.

Fig. 2. A specimen showing the calicular end and the costæ. There are eight large primary septa, and one is united to the columella. Magnified.

Fig. 3. A specimen showing the transverse epithecal markings. Magnified.

Fig. 4. Cross section, magnified. There are eight primary septa and several secondary. Magnified.

Fig. 5. View of a nearly perfect corallum, showing constrictions, costæ, and epitheca. Magnified.

Figs. 6, 7, 8. Portions of a corallum in which at one end there is an hexameral arrangement of the septa (fig. 7), and midway there is the usual octomeral arrangement.

Fig. 9. Corallum of *Conosmilia anomala*, Dunc.

Fig. 10. The calice, magnified, showing eight primary septa.

Fig. 11. Corallum of *Conosmilia lituolus*, Dunc. Magnified.

Fig. 12. The calice, magnified.

Fig. 13. }
Fig. 14. } The corallum of *Haplophyllia paradoxa*, Pourtales (from Pourtales's 'Deep Sea Corals').
Fig. 15. }

NOTE.—March 25, 1871.

Some days after this communication was sent to the Royal Society, Mr. J. GWYN JEFFREYS, F.R.S., forwarded me several specimens of *Guynia annulata* which he had found adherent by their sides to mollusca obtained from the Adventure Bank. These specimens are well preserved, and one of them shows the small commencement of the long cylinder of the coral. Others exhibit the columella and the large septa and the normal septal arrangement (octomeral). But one rather deformed coral exhibited on a fractured surface which was at right angles to the long axis six large septa instead of the usual eight: this of course required careful examination and explanation. The septa in the lower and therefore older part of the coral were clearly irregular in their growth; but a section midway between this portion and the fractured part established the interesting fact that the lower part of the corallum possessed the normal octomeral septal arrangement, and that the upper, in consequence of the abortion of two septa, had the Neozoic hexameral type. This is very suggestive in the matter of the evolution of hexameral from octomeral types, or rather from the tetrameral.

March 24, 1871.

IV. *On the Fossil Mammals of Australia.*—Part V. Genus *Nototherium*, Owen.

By Professor Owen, *F.R.S. &c.*

Received May 8,—Read June 15, 1871.

§ 1. *Introduction.*—The recognition of the genus which is the subject of the present paper was subsequent to that of *Diprotodón.* So much of the molar teeth as remained in the mutilated mandibles* transmitted to me, in 1842, by Sir Thomas Mitchell, C.B., from the bed of the Condamine River, indicated their transversely two-ridged character, and suggested at first sight that the fossils might belong to some smaller species of *Diprotodon.* Closer scrutiny, however, showed them to be parts of full-grown animals, and that they could not be the young of any larger extinct Herbivore.

Moreover, sufficient of the symphysial or anterior part of one of the mandibular fossils remained to demonstrate the absence of any incisor developed as a tusk or defensive weapon†, such as coexisted with the bilophodont molar teeth in the lower jaw of *Diprotodon.* The small portions of the enamel on the remaining bases of the molars (for the crowns of all had been more or less broken away) showed a smoother surface than that at the corresponding parts of the molars in *Diprotodon.* I was therefore led to recognize with much interest, in the fossils transmitted by my esteemed friend on his return to his duties as Surveyor General of the Colony of Australia, after the publication of the work‡ containing the first notice of *Diprotodon*, evidence of another genus of extinct herbivorous marsupials, second only in bulk to that first discovered, and I proposed for the smaller genus the name of *Nototherium*§.

Further comparison of the mandibular fossils referable to such genus indicated them to have belonged to two species, to one of which (fig. 1, p. 42) I was glad to attach the name of its discoverer (*Nototherium Mitchelli*); the other I proposed to call *Nototherium inerme*, as it afforded evidence of the absence of large incisor tusks. Whether any, or of what proportion, or in what number, incisors might have been present in the missing fore part of the fractured symphysis could not, of course, be determined; that which remained only gave the negative evidence as to incisors of the relative size and shape and persistent growth characterizing the *Diprotodon*‖.

* Owen, "Report on the Extinct Mammals of Australia, &c.," in Reports of the British Association for the Advancement of Science for 1844, 8vo, p. 223, plates 3 & 4.

† Ib. p. 231.

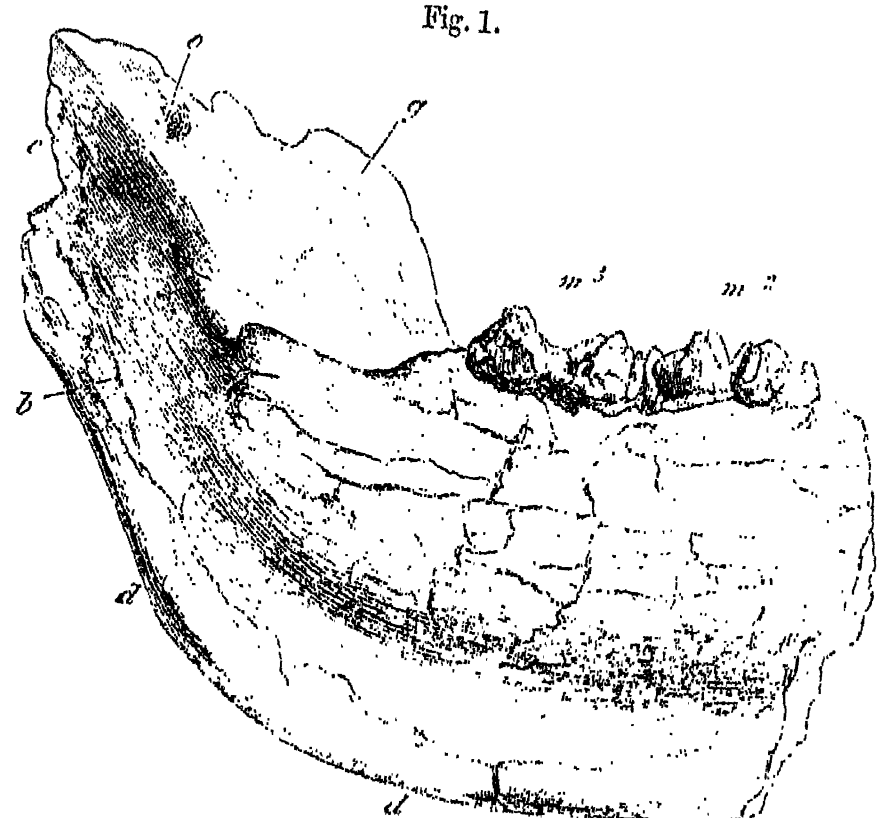
‡ 'Three Expeditions into the Interior of Eastern Australia,' vols. i. & ii. 8vo, 1838.

§ νότος, south, θηρίον, beast, 'Catalogue of the Fossil Mammalia and Aves in the Museum of the Royal College of Surgeons,' London, 4to, 1845, p. 314.

‖ "The lower fractured surface exposes the dental canal extending obliquely from without inwards below the

In the year 1845 I received from the accomplished and determined, but unfortunate, explorer of Australia, LUDWIG LEICHHARDT, a fossil mandibular ramus of a young Noto- there, showing the germ of an incisor which, in adult specimens subsequently acquired, proved to be a tooth of temporary growth with crown and fang distinct, as in *Macropus*,

Fig. 1.



Inner side of hind half of left mandibular ramus of *Nototherium Mitchelli* (½ nat. size), "On Extinct Mammals of Australia," Reports of the British Association for the Advancement of Science, vol. for 1844, pl. iv. fig. 3.

as will be shown in a subsequent part of the present memoir. One of these adult specimens included both rami, contributing satisfactory additional evidence of the characters of *Nototherium Mitchelli*. It was part of the series of fossils collected at King's Creek, Darling Downs, in 1845, and transmitted to London by Mr. BENJAMIN BOYD, where it was purchased by the Trustees of the British Museum, along with the cranium and lower jaw and other instructive parts of the skeleton of *Diprotodon*, described and figured in Part III. of the present series of Memoirs*.

A portion of maxilla with upper molar teeth of *Nototherium Mitchelli* also formed part of this purchased series.

In 1856 there was discovered in the same locality the skull, wanting the lower jaw, of *Nototherium Mitchelli*. This unique and valuable specimen came into the possession of FREDERIC NEVILLE ISAAC, Esq., by whom it was presented to the Australian Museum, then in course of formation in Sydney, New South Wales.

WILLIAM SHARPE MACLEAY, Esq., F.R.S., originator of the Quinary System and author

sockets of the anterior molars and then bifurcating; the outer and larger division terminating at the mental foramen, and an inner and smaller one extending forwards nearer the symphysis, but without any trace of a large incisor" (*op. cit.* p. 319).

* Philosophical Transactions, 1870, p. 519.

of works and monographs which gave great stimulus to the progress of philosophic zoology, published a notice of this remarkable fossil, naming it *Zygomaturus trilobus*, in a "Report on Donations to the Australian Museum during August 1857," which appeared in a Sydney newspaper of that date.

Photographs of the skull, made by the direction of the then Governor of Australia, Sir WILLIAM DENISON, K.C.B., were transmitted to Sir RODERICK I. MURCHISON, Bart., P.G.S., for presentation to the Geological Society of London. These photographs were placed in my hands, with the request to report upon them*. I had some time previously received from my friend GEORGE BENNETT, Esq., F.L.S., of Sydney, outline drawings of the same skull, from which materials I recognized it to belong to the genus *Nototherium*, and in all probability to the larger species, *N. Mitchelli*, of which the lower jaw, from the same formation and locality, had been previously received and added to the British Museum. I had written, on receipt of the 'Sydney Morning Herald' containing Mr. MACLEAY's Report and Notice of his *Zygomaturus*, to the author, suggesting the probability that his subject might prove to belong to the *Nototherium*, and expressing the wish for the opportunity of making the requisite comparisons by means of a cast of the skull; and I received a friendly and favourable reply in a letter dated 9th March 1858, in which Mr. W. S. MACLEAY writes:—"Every month a list of donations received is published in our local newspapers, and it is true that in one of such monthly lists I lately wrote on this '*Zygomaturus*' a few words which you appear to have seen. They are, however, principally intended to please the donor, and to induce him to send us more specimens. The name, from the 'tail' or process of the zygoma, was given on the principle we adopted of cataloguing every thing, were it only for the purposes of correspondence and exchange."—"You ask for a cast of the skull of the *Zygomaturus*, and I am glad to think that, long ere you receive this letter, you will have had in your hands a cast that Mr. WANT, a Trustee of our Museum, took home for the British Museum."

The characters afforded by this cast and by the outlines and photographs of the original specimen dispelled all doubt, in my mind, as to the skull and upper jaw and teeth belonging to the same species as the lower jaw of *Nototherium Mitchelli*, also discovered in the bed of King's Creek, Darling Downs.

But there were many points in relation to sutures and foramina which could only be determined by inspection of the original specimen. It could scarcely be expected, however, that a donation of such unique rarity would be despatched for that purpose from the Antipodes. But the Trustees of the Australian Museum have kindly directed photographs, on a larger scale than those originally sent by Governor DENISON, to be prepared and transmitted to me; and they have also liberally caused casts to be made of the principal specimens of bones and teeth of *Nototherium* subsequently acquired for the Australian Museum, which casts, with photographs of the originals, have likewise safely come to hand.

These and other evidences of the present genus, received at different times from various

* Quarterly Journal of the Geological Society, vol. xv. 1859, p. 168.

sources and localities in the Australian continent, will be duly acknowledged in the descriptions of such about to be given; and I propose at once to proceed with the results of the examination of the evidences at my command of the cranial structure of *Nototherium* *.

§ 2. *Skull.*—The singular shape and proportions of this part of the skeleton will be recognized at a glance of Plates II. and III. The occipital region (Plate III. fig. 1) represents the upper half of a transverse ellipse, being arched above; the straight line, or section, below is interrupted by the paroccipitals (4, 4), which descend on each side of the condyles (2, 2), about 2 inches below the level of the foramen magnum, *o*; the mastoids (8, 8) and squamosals (27, 27) bound the region externally. The breadth of the occiput at its base is 13 inches, the height at the mid line 7 inches. The surface inclines forward (Plate II. fig. 1, 3) especially at its mid third (Plate III. figs. 1 & 2, 3), but becomes vertical, or nearly so, as it arches outward. The surface is broadly undulate transversely, being concave at the mid third, convex at the two outer thirds. Nearly the whole of this surface is roughened by ridges and insertional impressions of nuchal muscles, the sharpest and most prominent of which is the medial vertical one (ib. figs. 1 & 2, 3), extending from near the upper border of the foramen magnum to the transverse ridge bounding the occiput superiorly: this ridge describes a low arch transversely; lengthwise it extends toward the upper surface of the cranium, describing an open angle with the truncate apex forward (ib. fig. 2) The condyles form the lower two thirds of the foramen magnum, save at the interval of seven lines between their lower ends (ib. fig. 3, 2, 2). From these they diverge as they rise with a vertical convexity, greatest at the lower half of the condyle, and more gradual toward the upper and outer end. The transverse convexity is more regular, and affects the hinder, outer, and under parts of the joint. The length of each condyle is 2 inches 7 lines, the extreme breadth is 1 inch 3 lines, the distance between the upper ends is 4 inches 6 lines. The surface towards the foramen is almost flat in the least diameter, gently concave or rather undulating lengthwise. The plane of the occipital foramen is vertical; its shape is a full ellipse, with the least diameter transverse; this gives 1 inch 8 lines; the long diameter is 2 inches.

A broad groove or channel, directed from below upward and outward, divides the condyle from the base of the paroccipital (4). This broad process inclines forward before it descends, its hinder plane being anterior to that of the convex part of the occiput above. The obtuse termination of the process is continued, with a curve upward and outward, by a thick and rugged ridge into the mastoid process (8), which, with the squamosal, bounds the occipital region laterally. The outer margin rises from the mastoid with a slight convexity for four inches before curving inward to the upper arch of the occipital ridge. A fracture of the outer table on the right side of the occiput exposes the extension to this part of the cranial walls of the air-cells continuous with larger cavities in advance.

* Dr. J. D. Macdonald, R.N., had the opportunity of seeing the remarkable skull which Mr. Isaac had sent to Sydney from King's Creek, and his 'Notes' thereon are quoted in my Paper in the 'Quarterly Journal of the Geological S[illegible]

The base of the huge zygomatic arch is continued (Plate II. fig. 1, $_{27}$), with a slight sinking inward, from the whole vertical extent of the mastoid ridge and from a part of the superoccipital; the lower end being formed by the tympanic, which is defined by a slight notch from the end of the mastoid process.

The parietal walls (ib. $_7$) extend from without inward and forward. From the short alisphenoid the parietal plate arches upward, with a strong convexity forward at its lower half (Plate III. fig. 3, $_7$); this subvertical part of the cranial walls forms the hind boundary of the vast subquadrate oblong vacuity combining orbit and temporal fossa (Plate III. figs. 2 and 3, *t*). The parietal or parieto-temporal wall (Plate II. fig. 1, $_7$) is divided from the occipital plane (Plate III. fig. 2, $_8$) by the superior or superoccipital arched ridge; it is divided from its fellow or opposite wall above by a flattened tract about an inch broad (ib. fig. 2, $_7$), near the superoccipital (ib. fig. 2, $_3$), but which expands as it advances from the parietal ($_7$) upon the frontal ($_{11}$) region. The parieto-frontal part of the cranium forms less than the middle third of the breadth of the entire skull as here completed by the enormous zygomatic arches. The frontal roof of the cranium, retaining its flatness transversely, gains a breadth of five inches, with a slight downward slope in profile (Plate II. fig. 1), and then (ib. $_{11}$) more abruptly arches down to the origin of the nasals (ib. $_{15}$), an arch being continued outward, on each side of the naso-maxillary pedicle, to the tuberosity (*s*) representing the antorbital or lacrymal process. There is a transverse depression above the origin of the nasal bone (Plate III. fig. 2, $_{15}$). The vertically convex outswellings of the frontal above and alongside this depression indicate the enormous air-sinuses within. The inner side or walls of the orbito-temporal vacuities sink sheer from the upper parieto-frontal tract to the outswelling of the maxillary molar alveoli (ib. $_{21}$), with a slight inclination inward. The greatest posterior depth of this cranial precipice is $6\frac{1}{2}$ inches.

At the junction of the alisphenoid with the parietal, near the bottom of the back wall, is a tuberosity. The diameter of the sphenoido-parietal part of the cranium is $4\frac{1}{2}$ inches; that of the skull at the corresponding part across, or including the zygomatic arches, is 16 inches! The cranium proper, from this singular constriction, gradually expands as it advances to the superorbital part of the frontals. If the cranial cavity concurred with its outer walls in shape it would be triradiate, two corridors extending along the transversely extended and antero-posteriorly contracted occipital part, and a third passage running forward from the mid line toward the face. But the singular departure in the outer walls from the normal shape of the brain-case is mainly due to a vast diploë of air-cells. The proper cerebral cavity makes no outward show, and it is insignificantly small in proportion to the entire skull.

Viewed from below (as in Plate III. fig. 3), the condyles ($_{2, 2}$) are divided by a deep notch; their lower ends descend a little below the level of the basioccipital ($_1$). This presents a rugged triangular tract in advance of the foramen, the apex being continuous with a sharp ridge longitudinally bisecting the surface of the basisphenoid. On each side of the tuberous tract and ridge is a wide and moderately deep depression, extending

from the lower end of the occipital condyles forward to the pterygoid plates or posterior aperture of the nares. These "basioccipito-sphenoidal depressions" are bounded laterally by a small tuberosity, by the inner surfaces of the occipito-petrous prominence, and by a ridge inclining mesiad to the hind part of the base of the pterygoid plate.

The basioccipito-sphenoidal part of the "basis cranii" is $3\frac{1}{2}$ inches in length, and 3 inches in breadth posteriorly. Its plane forms with that of the "basis faciei," or bony palate, lengthwise, an angle of 130°; the basis cranii sinking, the basis faciei rising, as they advance.

The fore part of the tympano-mastoid ridge (Plate II. fig. 1, $_{8, 12}$) appears to form the smooth flat hind wall of the articular surface for the mandibular condyle, unless the squamosal should abut against the mastoid beneath the petrotympanic: the cranial bones of this part are evidently modified by original antero-posterior compression. This post-glenoid process or wall is $2\frac{1}{2}$ inches transversely, and probably was of great vertical extent when entire; it is directed from within outward and rather forward. The articular surface has the same direction, and consists of a hind groove (Plate III. fig. 3, *g*) and a front bar, *i. e.* it is divided from before backward into a strong convexity and a deep concavity; both are slighly concave transversely; in that direction the extent of the surface is $3\frac{1}{2}$ inches; from before backwards it measures $1\frac{1}{2}$ inch. The malar ($_{26}$) descends to bound the outer part of the articular bar, to which it contributes a share of the articular surface. The outer end of the groove opens freely upon the base of the zygoma, which it slightly indents; the inner end is blocked by the descending part of the rugged petrosal.

The palatal part of the premaxillaries (Plate III. fig. 3, $_{22'}$) is feebly concave, 1 inch 5 lines across at the interval between the sockets of i_2 and i_3, then contracting to a breadth of 1 inch at the middle of the diastema (ib. *d*) between the incisors and molars: the length of this toothless tract is 2 inches 9 lines in a straight line. It is formed by a well-defined ridge gently curved inward until near the socket of the anterior molar, which part of the alveolar tract bends abruptly downward, 9 or 10 lines, below the ridge (Plate II. fig. 1, $_{21}$, d_3). The palate is deep transversely between the right and left anterior molars (Plate III. fig. 3, d_3, $_{21*}$), their interval in a straight line being 1 inch 10 lines. As the palate expands its transverse concavity decreases; its greatest breadth between the penultimate molars (m_2) is 2 inches 9 lines. Lengthwise the intermolar part of the bony palate (ib. $_{20*}$, $_{21*}$) is, anteriorly, gently concave, then convex, and again concave; it extends about an inch beyond the last molars, is bounded behind by a thick low rough ridge, a median forward continuation of which divides the back part of the bony palate into two shallow rough depressions or channels leading outwards to behind the last alveoli. The bony palate appears to be entire; its length from the interspace of the alveoli of the front incisors ($_{22*}$) is 11 inches 6 lines, from between the alveoli of the front molars to the hind border it is 7 inches 6 lines.

The huge and extraordinary zygomatic arches (Plates II. & III. $_{27}$, $_{26}$, $_{21}$) extend straight forward in parallel lines for more than half the length of the entire skull (Plate III.

figs. 2 & 3), then bend abruptly downward and arch transversely inward to abut against the middle third of the alveolar plates of the maxillaries, a thick transversely extended process (Plate II. figs. 1 & 2, $_{21'}$) being continued downward from the angle of the inward curvature. From the hinder origin or "pier"($_{27}$) each arch gains, as it advances, a vertical extent of 4 inches 3 lines; then contracts to one of 3 inches, again expanding slightly in the vertical direction, and greatly in the transverse one, before the inward twist to form the maxillary pier or abutment. The inner surface of the arch is smooth and slightly concave; the outer surface is rough, convex, and outswells into two large protuberances, one at the part (*e*) anterior to that supporting the joint for the lower jaw, the other and larger (fig. 2, *f*) at the angle formed by the down-bending of the arch to the orbital floor; the latter is most prominent and best defined. The floor of the orbit (ib. fig. 1, *r*) is of comparatively small extent, limited to the inner or mesial half of the inwardly bent part of the zygoma, of a triangular form, indicative, with the inner orbital concavity leading to the antorbital process (*s*), of the small relative size and low position of the eyeball; with this position the foramen opticum corresponds. The extent of the anterior inwardly bent part of the zygoma is 5 inches. From the lower angle of the bend is continued downward the process ($_{21'}$) for an extent of 3 inches, with a twist, making its sides look forward and backward, its borders outward and inward. Its breadth is $2\frac{1}{2}$ inches, its termination subtruncate; from its inner border to the alveolar part of the maxillary, between the penultimate and antepenultimate molars, is 3 inches 6 lines, giving the span of the arch extending transversely from the anterior root of the zygoma to the masseteric process, the end of which reaches below the level of the upper grinding-teeth (Plate II. fig. 1, $_{21'}$). The anterior root of the zygoma is three-sided: one, the upper horizontal surface, forming the floor of the orbit, has a fore-and-aft extent of 2 inches; the anterior and posterior surfaces converge to a thick lower border, which is above the interval between m_1 and m_2, terminating about 10 lines above the outlets of the sockets of those teeth. The antorbital foramen (ib. $_{21}$) is vertically elliptic, 10 lines in long and 6 in short diameter, situated 1 inch 9 lines in advance of the orbit, and about 2 inches above the outlet of the anterior molar (d_3). The antero-posterior extent of the maxillary alveoli, in a straight line, is 7 inches; their outlets describe a gentle convexity downward as well as outward, the right and left series diverging from the anterior pair to the fourth and incurving slightly at the last pair (Plate III. fig. 3, d_3, m_3). The outer roots of the contained molars cause corresponding prominences of the sockets, giving an undulatory surface to that part of the upper jaw (Plate II. fig. 1). This extends, perhaps in conjunction with the palatine bone, about an inch beyond the last molar, with an upward slope.

The breadth of the hind part of the palate here is 3 inches 3 lines. The posterior nares form a triangular aperture, with the base above the palate, 2 inches 3 lines broad, thence contracting as it extends obliquely upward and backward to a point at the fore end of the basisphenoid ridge; the length of the aperture from this point is 4 inches 6 lines. The aperture is bounded laterally by the pterygoid plates.

If, as in the skulls of Mammals generally, we regard the part anterior to the orbits as the facial division, which is often the longest, the corresponding part in *Nototherium* offers the strangest and most anomalous form and proportions in the mammalian class. It looks like a mere pedunculate appendage to the rest of the skull. Instead of tapering to the end, as is usually the case, it expands forward from its base of attachment both vertically (Plate II. fig. 1, $_{15}$, i_1) and transversely (Plate III. fig. 2, $_{15}$, $_{22''}$). The vertical diameter at the base, or from the depression at the root of the nose to the fore part of the maxillary alveolar process, is 4 inches 9 lines; the same diameter at the fore end, from the tips of the nasal bones ($_{15}$) to the first incisive alveoli (i_1), is 6 inches 6 lines. The breadth of the face at the outsides of the antorbital foramina is 2 inches 6 lines; the same dimension across the nasal processes of the premaxillaries ($_{22''}$) is 6 inches. The length of the facial part of the skull from the antorbital foramen (Plate II. fig. 1, $_{21}$) to the fore part of the premaxillary ($_{22'}$) is 5 inches 8 lines.

The nasal bones ($_{15}$) appear to expand as they advance, chiefly transversely, for four fifths of their extent, then abruptly contract, from their outer borders, to terminate in a slightly deflected obtuse apex: their mesial suture appears to lie in a longitudinal chink or depression at the anterior third (Plate III. fig. 2, $_{15}$), but the chink does not extend to the conjoined apices. The sides of the most expanded part of the external nostril, contributed by the premaxillaries, swell into low and large, rather rough, tuberosities ($_{22''}$); between these the upper surface is almost flat, like a platform.

The premaxillaries ($_{22}$), which unite with the nasals ($_{15}$), as in *Phascolarctos* (Plate II. fig. 3) and *Phascolomys* (ib. fig. 4), send their nasal processes upward, outward, and forward, where they expand and terminate, each in a tuberosity which projects below and a little in advance of the one above mentioned. These tuberosities, with the mesial prominence of the apices of the nasals, give a trilobate character to the upper boundary of the external bony nostril in *Nototherium* (fig. 2), exaggerating that in *Phascolomys* (fig. 4).

The premaxillaries ($_{22}$) contract and descend, below the nasal processes, as vertical plates; slightly expanding again, below, to form the alveoli of the incisors, especially of the larger anterior pair: the outer surface of these alveoli appears to have been coarsely rugous. The inner walls of the alveoli rise, conjoined, as a vertical plate of bone, 3 inches above the outlets, and extend backward in close contact to form or support the beginning of the "septum narium." The space between the premaxillary septal plates and the superincumbent ends of the nasals is little more than an inch, which gives the vertical diameter of the nostril at that part; its transverse diameter is 4 inches. The antero-posterior extent of the alveolar part of the premaxillary is 2 inches 6 lines. The fore-and-aft diameter of the outlet of the first incisor is 1 inch 2 lines; the transverse diameter is 10 lines. The outlets of the smaller second and third incisors are subcircular; each has a diameter of 6 lines.

The cranial characters above described from casts, drawings, and photographs, I have been enabled to test by actual fossils of portions of the upper jaw and skull.

The first of these is a fragment of a right maxilla with two molars (m_1, m_2) *in situ*.

It shows part of the front pier of the maxillary arch, including its posterior surface, which springs from the alveolar plates on the vertical parallel with the interval between the two lobes of m_1, at its lower end, and extending as it rises with a curve convex backward to overhang part of the hind lobe of the same tooth. Sufficient of this maxillary zygomatic process remains to exemplify the difference between *Nototherium* and *Diprotodon* in the antero-posterior extent or thickness of this "pier;" it is characteristically greater in the smaller Herbivore, and of itself would save the palæontologist from being led astray by the close general resemblance of the upper molars of *Nototherium* with those of *Diprotodon*. The present fragment being from a young specimen, the dental lobes show well their vertical curve concave forward, and the transverse curve of the edge of the wedge concave backward. I availed myself of this fragment to expose the front roots of the anterior molar and the hind root of the posterior molar; but these, with other dental characters, will be noted in the section on the teeth of *Nototherium*. The present specimen afforded the subject of fig. 8 in Plate IX.: it shows a part of the convex roof of the alveolar tract which projects into the orbito-temporal vacuity, and the contiguous groove for the superior maxillary nerves and vessels.

The second cranial specimen is a larger proportion of the left maxilla with three molars *in situ* (d_4, m_1, m_2), part of the socket of the first (d_3), and the base of the crown of the last (m_3) rooted in its socket.

A portion of the bony palate extends with a slight upward curve, inward, from the sides of the sockets of d_3, d_4, and more distinctly inward from those of m_1 and m_2. A breadth of 1 inch 6 lines is preserved (opposite d_4): the fracture reduces the breadth to 6 lines as it extends backward to the alveolus of m_3. So much as is preserved of the bony palate confirms the inference of the entireness of the bony roof of the mouth deducible from the cut and photograph of the entire cranium, as far back at least as the sockets of m_3, right and left. The hind part of the origin of the zygomatic process of the maxillary is here at the vertical parallel of the interval between m_1 and m_2, consequently rather further back than in the former fragment. The worn surfaces of m_1 and m_2 show the present to have come from an older individual, as will be subsequently pointed out in detail. An extent of 3 inches of the massive maxillary pier, as its origin extends from behind obliquely upward and forward, is here preserved; the thickness of the process is 1 inch 3 lines. The height of the alveolar process or tract at the last two molars is 2 inches 9 lines. The transversely convex or arched roof of these sockets is, relatively, less broad and prominent than in the Wombat; its extent and proportions resemble more the corresponding part in the Kangaroo, conformably with the common character of three-rooted teeth of limited growth, which contrasts with that of the large undivided bases of the corresponding molars in *Phascolomys*, retaining their formative matrices, and making a proportional prominence outside the "superior maxillary channel." This channel in *Nototherium* describes a curve convex outward as it courses forward to perforate the antorbital part of the maxillary and emerge upon the outer surface of that bone (as the 'antorbital foramen,' 21, fig. 1, Plate II.).

The third portion of the skull of *Nototherium* includes part of the right maxillary with three molars (d_4, m_1, m_2) *in situ*, and part of the right palatine bone (Plate IX. figs. 6 & 7). The teeth are more worn than in the preceding specimen: the fossil is part of an aged individual; the teeth, moreover, show a superiority of size compared with those of the last described fragment, answering to the difference one sees between the molars of the full-grown male and female Kangaroos.

The hind surface of the maxillary pier of the zygomatic arch here lies vertically parallel with the fore half of the front lobe of m_2: an extent of 3 inches 3 lines is preserved of the origin of the pier as it passes forward and upward, where the fracture of the maxillary traverses the interval between the sockets of d_3 and d_4. The bony palate arches upward and inward from the inner walls of the sockets of m_1 and m_2, in as great a degree as from those of the socket of d_4. The extent preserved, in a straight line from the outlets of the alveoli, is 2 inches. The palato-maxillary suture begins at the inner or mesial fractured surface of the bony palate opposite the hind lobe of m_1; near the interval between m_1 and m_2 it extends outward and backward with an oblique curve to near the inner side of the outlet of the socket of m_2. Its relative position to the molars agrees with that of the palato-maxillary suture in *Phascolomys latifrons*; in *Macropus laniger* the suture begins, mesially, at the transverse parallel of the interval between m_2 and m_3, at least in an example with those molars in place and use.

The palatine bone, like the maxillary alveolar tract, has been broken at the part behind m_2, the broad single posterior root of which is exposed. But at the fractured surface of the palatine there occurs, just opposite or parallel with the back part of m_2, a small tract of the natural smooth unbroken surface of the palatine, indicating a posterior palatal vacuity, on the parallel of m_3, as in *Phascolomys*. The thickness, vertically, of the fore part of the bony palate here preserved is 1 inch, of the hind part half an inch.

In the younger, probably female specimens, the same admeasurements give 6 lines and 2 lines.

Contrasting the difference of size, shape, and relative position of so much of the maxillary zygomatic process and bony palate as is preserved in the two specimens just described, one is at first inclined to deem them to have come from different species of *Nototherium*; and three species of the genus are indicated by mandibular characters.

But in reference to the progressively backward extension of the zygomatic process of the maxillary, this may be coincident with the progressive growth of the alveoli of the hinder molars, as these teeth come into use; in like manner, as their crowns are pushed down to the line of wear in the ratio of the abrasion of their wedge-shaped ridges, so the alveoli will cling to and follow the roots, growing as they lengthen, and giving a curve or concavity to the palatal surface not present or needed in the less worn condition of m_1, m_2, and m_3, in younger individuals.

With the foregoing evidences of the cranial characters of *Nototherium* we may safely proceed to bring them out, or add to their saliency, by comparison with those in other extinct and in existing Marsupialia.

The skull of *Nototherium* is shorter in proportion to its breadth and depth than in *Diprotodon*, and differs in the singular way in which the maxillary or facial part is bent up upon the cranial part, exemplified in figure 1, Plate II., and by the angle, before noted, which the bony palate forms with the basis cranii. The shortness is mainly due to that of the antorbital extent of the skull; the diastema between the incisors and molars is relatively as well as absolutely less than in *Diprotodon*. The Notothere resembles the Koala (ib. fig. 3) and Wombat in the small proportion of the skull in advance of the orbits; the *Diprotodon* is more like the Kangaroos in the length of this part. The terminal expanse and lateral tuberosities of the upper half of the bony nostril is a peculiarity of *Nototherium*; but it is instructive to note them in both *Phascolarctos* and *Phascolomys* (Plate II. fig. 4); the fore part of the bony muzzle is expanded laterally by an outward swelling of the front border of the premaxillary (ib. $_{22}$) where it joins the nasal (ib. $_{15}$).

In the form, especially breadth, of the external nostril the Notothere resembles the Wombat, while the Diprotodon is more like the Kangaroo in this respect; but no known existing Marsupial shows the septal plates developed from the premaxillaries at the entry of the nasal passages, as in both *Nototherium* and *Diprotodon*. The Wombats make the nearest approach to this peculiarity.

The Notothere surpasses the Diprotodon in both the absolute and relative size of the zygomatic arches. This difference is very striking when a front view of the cranium (as in figure 2 of Plate II.) is compared with the similar view given of the Diprotodon's skull in Plate xxxv. fig. 2, in the Philosophical Transactions for 1870.

This most extraordinary feature in the cranial organization of the present large extinct Herbivore leads me to submit the following remarks.

The zygomatic arches are relatively stronger and wider in Proboscidians than in Ruminants and Solipeds; they are widest and thickest in the bilophodont Dinotheres, the temporal fossæ being of corresponding capacity. Still more developed are these arches in the Manatees, the Tapirs, and the bilophodont Megatheres, especially in the vertical extension of the bone giving attachment to masticatory muscles. It would seem that the working of opposed double-ridged grinders required greater strength and more direct horizontal pull of the masseteric muscular fibres than the working of the more complex but flatter molars of the Ox, Horse, Rhinoceros, or Elephant. The phytophagous Marsupials have the grinding-surface of their many massive molars raised into prismatic cones or transverse ridges, and their skull is remarkable for the great strength, size, and span of the zygomatic arches. The descending process from the fore and under part of the arch, for extending the origin of the premasseter muscle, adds to the zygomatic complexities and characterizes the *Poëphaga* among existing Marsupials. This osteological feature is not found in any gyrencephalous Herbivore; but it exists, with a different relation to the constituent bones of the arch, in the lissencephalous Sloths, Megatherioids, and Glyptodonts. In the Nototheres the zygomatic development reaches its maximum, with the dependent process extending from the maxillary element

of the arch as in other Marsupials. The muscular force operating on the mandible, both for biting and chewing, was very great, indicative of unusual resistance in the alimentary substances to be ground down. The grip of the front incisors brought by the shortness of the face and jaw within the power of the crotaphyte muscles in a degree proportional to the proximity of the inserted movers must have been like that of a vice.

§ 3. *The Mandible.* A. *Nototherium Mitchelli.*—The mandible (Plate IV.) discovered in the bed of King's Creek, a tributary of the river Condamine, Darling Downs, which was purchased of the collector by Mr. BENJAMIN BOYD, and subsequently, with the rest of Mr. BOYD's collection, acquired by the British Museum, is from the same formation and locality as the skull above described, which fell into Mr. ISAAC's hands.

This mandible agrees so closely, not only in the shape, structure, and other characters of the teeth, saving the difference of upper and lower, but also in the dimensions of these and of the proportion of the jaw-bone preserved, that it might well have been part of the same individual; it certainly belongs to the same species.

Comparing the type specimen of *Nototherium Mitchelli*, Ow.*, with the answerable part of the above-mentioned mandible, the correspondence in size and configuration is such as to support the reference of the present more complete specimen to that species.

The depth of the mandible behind the last molar is 3 inches 9 lines in the first described, it is 3 inches 8 lines in the present specimen; the thickness of the mandible below the last molar is 2 inches 6 lines in both specimens. The antero-posterior extent of the two last molars in the original fragment with mutilated crowns is 3 inches 4 lines; in the more perfect mandible (Plate IV. figs. 1 & 2; Plate X. figs. 1 & 2, m_2, m_3) it is 3 inches 6 lines; from the back of the last molar to the entry of the dental canal (Plate IV. fig. 2, *o*) is 2 inches 9 lines in both specimens. The place and degree of inflection of the under margin and angle of the jaw (ib. *a* & *d*) are the same in both.

Referring on these grounds the mandible (Plate IV. figs. 1 & 2) to *Nototherium Mitchelli*, the cranium and upper jaw answering to that lower jaw must be referred to that species.

The mandible in question consists of the two rami mutilated at both ends, but fortunately retaining their natural confluence at the symphysis, of which a longitudinal extent of 3 inches 8 lines is preserved (ib. figs. 2, 3, *s*); this gives the angle of divergence of the horizontal rami from the place of confluence (ib. id.). It shows that the interval between the right and left mandibular condyles agreed with that between the articular cavities in the skull (Plate III. fig. 3, *g*, *g*); and that the distance of the condyle from the fore part of the first molar (d_3) was the same as that, viz. 12 inches, from the fore part of the first molar to the joint for the condyle in the upper jaw.

So much of the ascending ramus as is preserved, which closely corresponds with that in the type jaw, shows the same oblique direction of the curve (Plate IV. fig. 1, *a*, *b*, *d*)

* "Report on the Extinct Mammals of Australia, &c.," in Report of the British Association &c. for 1864, p. 13, pl. 4; and Cut, fig. 1, p. 42 (*suprà*).

by which the lower border graduates into the hind one of the rising branch: the curve changes slightly on rising to the level of the alveoli, being then feebly concave above the anterior inflected part of the lower margin; it becomes convex where the border is again inflected, and above this the hind border of the ascending ramus, after contracting, expands transversely, apparently to support the condyle. The angle or anterior inflection (*d*, *d*) is but slightly bent inward, with a thick and smooth border; the longitudinal extent of this inflected part is about 4½ inches, closely repeating, as far as it is preserved, the characters of the more perfectly preserved angle of the type specimen (Cut, fig. 1, *d*, *d*)*. An oblique longitudinal wide and shallow channel intervenes on the inner side of the ramus between the inflection (Plate IV. fig. 1, *d*, *d*) and the low tuberous termination† of the postalveolar ridge (ib. & fig. 2, *t*), about an inch and a half behind the socket of the last molar (m_3). This channel is continued backward with a partial interruption, caused by the forward extension of the inflected angle or hind border of the ascending ramus (Plate IV. fig. 2, *a*, *e*). This part is broken away in the type specimen.

In no part of the oblique channel (ib. *b*) occupying and mainly forming the inner surface of the ascending ramus of the jaw is there any trace of inlet of a dentary canal; in this respect, as in the somewhat unusual position of that inlet or entry, the present mandible agrees with the type fragment‡. Some nerve or vessel has left its impress along the middle of the channel, but has quitted it for contiguous soft parts without penetrating the bone.

The outer surface of the ascending ramus rises from the line of the anterior inflection (*d*) with a feeble vertical concavity, speedily changed to a convexity curving outward to the thick obtuse lower boundary (Plate II. & Plate IV. fig. 1, *h*) of the ectocrotaphyte depression (ib. *f*). The fore part of this depression is formed by the corresponding part of the rising ramus (ib. and fig. 2, *q*), which commences opposite the hind part of the last molar (m_3), and at a distance outside it of 1 inch 3 lines. The base of the "coronoid" plate (Plate IV. fig. 2, *q*, *h*) describes a curve, concave outward, of which base an extent of 5 inches (in a straight line) is preserved. The process is broken off in both rami; it was thickest at the fore part of its base (Plate IV. fig. 4, *q*), which here gives half an inch. The dental nerves and vessels groove the inner and back part of the base of the coronoid before penetrating it obliquely in the same position (at *o*, figs. 1 & 2) as that in the types pecimen (Cut, 1, *o*).

Between the postinternal alveolar process (Plate IV. figs. 1, 2, *t*) and the base of the coronoid process, is an irregular shallow channel (ib. *u*), narrowing as it passes backward to the dental canal (*o*). The depth of the mandibular ramus at the back of the last tooth-socket is 4 inches, the thickness of the ramus at the fore part of the origin of the coronoid process is 2 inches 6 lines.

The interspace between the right and left last socket is 3 inches 6 lines. The breadth of the mandible, taken anterior to the origin of the coronoid process, is 7 inches 8 lines; whence the jaw gradually expands to the condyles. We may estimate its breadth at the

* *Op. cit.* pl. 4. figs. 3 & 5, *a*. † *Loc. cit.* figs. 2 & 3, *b*. ‡ *Loc. cit.* fig. 3.

outsides of these, from the cavities (Plate III. fig. 3, g, $_{27}$) receiving them, to have been 1 foot, or thereabouts.

The outer surface of the horizontal ramus (Plate II. fig. 1, $_{32}$, q) is smooth, very convex vertically where it advances from the ascending ramus, but rising with a slight concavity to the outlets of the sockets; the convexity subsides as the jaw advances and the surface ascends more vertically to the outlets of the three anterior molars (ib. d_3, d_4, m_1), but it continues the vertically convex curve to the lower border. The thickness of the ramus before inbending to the symphysis is 2 inches; its height where it joins its fellow at s (Plate IV. fig. 2) is 3 inches 5 lines. At the lower and back part of the symphysis is a transverse roughish crescentic depression (Plate IV. fig. 3, v) for muscular insertion. The general longitudinal lay of the outer surface of the horizontal ramus is a feeble convexity forwards as far as below the second molar (d'_4), where it begins to change to a concavity leading on to the symphysial part (fig. 1, $_{32}$–k), containing, anteriorly, the sockets of the incisors. On the vertical parallel of the fore part of the first molar socket, about halfway between the upper and lower borders of that part of the ramus, is an outlet of the dental canal (ib. $_{32}$); it is subcircular, 5 lines in long diameter.

The inner surface of the horizontal ramus (Plate IV. figs. 1 & 2, i) sinks sheer below the outlets of the last socket, and with a slight vertical convexity from that of the penultimate molar; it is at first feebly concave, then convex to the back part of the symphysis, and the surface is uniformly concave at the upper part of the symphysis (ib. fig. 2, s^*), between the three anterior sockets of the right and left sides. The longitudinal lay of the inner wall of the ramus is feebly convex posteriorly, changing to a concavity deepening into the back and upper part of the symphysis. This junction of the right and left rami is completely ossified without a trace of the primitive separation shown in Plate VI. figs. 2, 3, 4, s, s', s^*; herein contrasting strongly with the condition of the joint in the Kangaroo†.

The hind surface of the symphysis (Plate IV. figs. 2 & 3, s), vertically convex and smooth, is on the vertical parallel with the back lobe of third molar (m_1), near, but not quite extending, to the interspace between its socket and that of the fourth molar (m_2). The upper surface of the symphysis (ib. fig. 2, s^*, s) between the three anterior molars (m_1, d_4, d_3) is a rather deep smooth longitudinal canal, the margins of which begin to be encroached on by a diastemal ridge (ib. k), continued forward from the socket of d_3 with a slight curve convex inward.

The antero-posterior extent of the five molar alveoli is 7 inches 5 lines. The breadth of the anterior division of the first socket is 3½ lines, of the posterior division 5 lines; the depth is shown in the jaw of the young *Nototherium* (Plate VI. fig. 5, l). The sockets of the other molars increase in breadth to the anterior division of the last, which is 1 inch 1 line across. The alveolar plate rises in an angular form at the intervals of the sockets, and at those of the diverging roots of each tooth on both outer and inner sides of the jaw.

† OWEN, Osteology of the Marsupialia, 'Anatomy of Vertebrates,' vol. ii. p. 350.

At the fractured part of the symphysis are parts of the bottoms of a pair of incisive alveoli; that on the left side gives a transverse breadth of 9 lines and a vertical one of about 1 inch; but the lower wall is broken away from the base. A still smaller portion is preserved on the right side.

The indications suffice to show that the incisors were not developed as tusks, of size and proportions fitted for offensive or defensive purposes, as in *Diprotodon*; their base and socket not extending backward beneath any of the molar alveoli, at least in the adult. Not more than an inch and a half of the toothless part of the symphysial end of the lower jaw has been preserved in the present specimen, and that only on one (the left) side.

Accepting the evidence from size and proportion in the preserved parts of the present mandible and its dentition, in proof of its appertaining to a full-grown individual of the same species as the skull above described, the length of the part of the lower jaw with its incisors, in advance of the molar series, can be estimated and restored from that of the premaxillary and its incisors anterior to the molar teeth in the upper jaw. This estimate gives from the fore part of the anterior molar socket of the mandible to the tips of the pair of lower incisors an extent of at least four inches and a half.

Complete as is this lower jaw compared with previously received specimens, including the one originally described, the relative extents of the sockets and protruded parts of the lower incisors would have remained to be determined.

Fortunately a mutilated mandible, but with the symphysial end nearly if not quite entire, has been received by the Trustees of the Australian Museum, Sydney, and a plaster cast of this specimen has been prepared and transmitted, with their characteristic liberality and promptitude, to the Trustees of the British Museum.

In this specimen an extent of the jaw forming the sockets of the pair of incisors (Plate V., *k*, *i*), 2 inches 6 lines anterior to the first molar (ib. fig. 3, d_3 & s^*), has been preserved; but at this distance, the incisors with, perhaps, some small part of the fore part of their sockets have been broken off. The symphysis dwindles vertically and transversely to the condition of mere sheaths of the two approximate teeth, such sheath in no part of the fractured surface exceeding three lines in thickness, and where the bone comes nearest to the fracture it thins off to a fine edge (ib. fig. 4). As far as a cast can be trusted, part of the natural outlet of the sockets is shown below the teeth (ib. fig. 2, *s'*), the alveolar wall having extended further forward at their upper part†.

The vertical diameter of the fractured or partially fractured end of the symphysis at the mid line is 1 inch 6 lines; the transverse diameter is the same. The broken surface, including the roots of the incisors (Plate V. fig. 4, nat. size), is of a subquadrate form, with a mesial groove above (*s'*) and a slighter one below.

The lower contour of the mandible is continued, without interruption, but with gradual loss of convexity, from the inflected border (fig. 1, *d*) to the outlet of the incisors (*i*).

† See "Memoir on *Diprotodon*," Philosophical Transactions, 1870, Plate XLI. fig. 2, *s*, where the same form of incisive alveolar outlet is shown in the mandible.

At the upper part of the symphysis the ridge (fig. 3, *k*), of which the beginning or hind part was noted in the description of the preceding specimen (Plate IV. figs. 1 & 4, *k*), is here seen to converge toward its fellow for the extent of an inch, then to be continued straight forward, broadening and subsiding. The pair of ridges form the sides of the smooth channel (*s**), grooving the upper surface of the symphysis, and gradually shallowing to the fore end. Posteriorly the channel rapidly widens to the intermolar space, then gradually expands, preserving or gaining depth to the hind border of the symphysis (*s*). The entire length of this confluent tract of the mandibular rami is 5 inches 10 lines; the thick rounded hind border is on the vertical parallel with the hind lobe of the third molar (m_1). It is satisfactory to find this character of the former mandible of *Nototherium Mitchelli* (Plate IV. fig. 2, *s*) here repeated. The under part of the hind end of the symphysis shows the insertional depressed surface (Plate V. fig. 2, *v*, *v*, of similar size and shape to that in the subject of Plate IV. fig. 3, *v*). The symphysis is subcompressed anterior to the molars, but the transverse diameter diminishes less gradually than the vertical one.

The present mandible is of a full-grown and, from the wear of the teeth, rather aged individual. The last three molars and a portion of the second are in place in the right ramus: the first, second, and part of the third molars remain in so much as is preserved of the left ramus.

The fore-and-aft extent of the molar alveoli is 6 inches 10 lines; that of the three hindmost is 5 inches 2 lines. I give this measurement, as well as the first, to show the close correspondence in size of the present with the preceding mandible of *Nototherium*: the present specimen is rather smaller; the bone is rather more slender; the vertical diameter, for example, of the ramus anterior to the foremost molar-socket is 2 inches 4 lines, in the subject of Plate IV. it is 3 inches; the vertical diameter behind the socket of the last molar in the subject of Plate V. is 2 inches 10 lines, in that of Plate IV. it is 3 inches 9 lines, in the type jaw† it is 3 inches 8 lines. With the closer conformity in the molar series, I infer the more slender proportions of the present mandible to be sexual, and to indicate its having come from a female Notothere.

Rather more of the base of the coronoid process (Plate V. figs. 1 & 3, *q*, *o*) is here preserved than in the subject of Plate IV.; it occupies the same proportion, and shows the same shape and curve as in that jaw; the dental canal perforates its hind part in the same position and with the same obliquity. The postalveolar process, broken as in the former mandible, and as it usually is in these Australian fluviatile fossils, holds the same relative position to the last molar tooth as in the male jaw. The smooth oblique channel between the fore part of the coronoid and the last alveolus has a breadth of 9 lines in the female, instead of 12 lines as in the male specimen. The anterior inflected angular border repeats the characters of the part in that specimen, but is not entire; the exceptionally perfect condition of the part in the type mandible‡ gives consequently valuable evidence of this character.

† *Loc. cit.*; and Cut, fig. 1

‡ *Loc. cit.*; and Cut, fig. 1, *d*.

The commencement, an inch above the anterior angular inflection, of the posterior inflected margin (Plate V. figs. 1 & 5, *a*) and the corresponding outswelling at the outer part of the ascending ramus (ib. fig. 5, *h*) indicate more definitely than in the first described mandible the part from which the neck of the condyloid process has been continued. The breadth of the back part of the jaw here is 2 inches 2 lines.

The anterior outlet of the dental canal is, as in the former mandible, on the same vertical line as the fore part of the first molar; but it is placed rather lower down: it is of similar size and shape.

A third example yielding Nototherian mandibular characters is also from the freshwater deposits of Darling Downs; it was discovered at Eton Vale by EDWARD S. HILL, Esq., and was presented to the British Museum by Sir DANIEL COOPER, Bart. It is part of the left ramus of an adult and seemingly male jaw, and includes the sockets of the last three molars with the penultimate and last of these teeth in place, but mutilated. It retains a similar proportion of the ascending ramus to that in the two preceding jaws, but with more of the fore part of the base of the coronoid process. The vertical diameter of the ramus behind the last molar socket is 3 inches 9 lines; the thickness of the jaw below that socket is 2 inches 7 lines.

From the hindmost socket to the orifice of the dental canal is 2 inches 8 lines. The postalveolar process with the base in the Nototherian position is, as usual, broken away, like most projecting parts in these rolled and transported drift-fossils. The fore part of the coronoid rises to 1 inch and 9 lines above the dental orifice, but at that height has been fractured. The antero-posterior extent of the two last sockets is 3 inches 6 lines, as in the first described mandible, with which all the other characters of the present specimen correspond so far as they are shown. I refer it, therefore, to a large old male of *Nototherium Mitchelli*. The marks of torrential action are very plain in this water-worn fossil: it is massive and heavy from some mineral infiltration.

A fourth rolled and mutilated specimen from the same locality, contributed by the same liberal donor, retains the last three molars and the socket of the second, with the hind part of the symphysis, showing the same vertical relative position to their molar (m_1) as in the former specimens of *Nototherium Mitchelli*. The teeth, so far as they are preserved, agree in size, shape, and proportion with those of that species. The ascending ramus has been broken away behind the last alveolus and the beginning of the base of the coronoid process. The dental canal is here exposed an inch below that part of the process, and half an inch from its outer side.

The fore-and-aft extent of the three last sockets is 5 inches 5 lines. The depth of the ramus at the interspace between the last two sockets is 4 inches 2 lines in a straight line; below the interval between the penultimate and the antepenultimate molars it is 4 inches 3 lines. In the first described mandible the same admeasurement is here 3 inches 9 lines; in the type jaw it is 3 inches 7 lines; in the second and supposed female jaw it is 2 inches 10 lines. Between this and the mandibular fragment under description the difference of depth of the horizontal ramus seems too great for mere sexual variety; yet the three last molars are not at all larger than, or in any appre-

ciable degree different from, those in the subject of Plate V. But, besides the greater depth, the outer surface of the jaw is rather less convex vertically beneath the third molar (m_1) than in the three preceding specimens. Nevertheless I cannot feel that I have grounds for propounding any distinction of specific value for the Nototherе yielding the present fossil. The fracture through the hind part of the symphysis exemplifies the complete bony confluence of this part, and the non-existence therein of the wide alveolus of a large scalpriform tusk. The transverse fracture anterior thereto at the interval between the first and second molars exposes the dental canal, of 4 lines diameter, situated 2 inches below the outlet of the socket, and 1½ inch above the lower surface of the symphysis.

The fifth mandibular specimen of *Nototherium Mitchelli* is from the freshwater beds traversed by Gowrie Creek, Darling Downs; it was there collected by HENRY HUGHES, Esq., by whom it was presented to the Natural-History Society of Worcester. This specimen is chiefly valuable for the more perfect and less worn condition of certain of the molar teeth. It consists of a right ramus mutilated (as most of these fossils from river-beds are) at both ends. The relative position of the back part of the symphysis and of the entry of the dental canal, with the general size and proportions of the best preserved parts of the ramus, show the specimen to have belonged to the *Nototherium Mitchelli*; and it agrees most closely with the more perfect mandible in the Australian Museum at Sydney, which I have referred to the female of that species.

The subject of Plate VI. is an instructive specimen of a mandibular ramus and dentition of a young Nototherе; it was transmitted to me, in 1847, by the enterprising and unfortunate explorer of Australia, LUDWIG LEICHHARDT, to whom I had been previously indebted for the account of the geology of the locality yielding this and other remains of extinct Marsupials, which was communicated to the Society in a former Memoir*.

I incline to refer this specimen, from the size of the incisor and of the three anterior molars, to *Nototherium Mitchelli*. The generic indications in the present fossil will be noted in § 4, on the teeth of *Nototherium*: the characters of the bone exemplify mainly those of immaturity. It consists of a right ramus, which, being figured of the natural size in Plate VI., precludes the need of noting dimensions. The antero-posterior extent of the three anterior molar-sockets will be seen to agree with that in the mature mandible, Plate V.

The ascending ramus has been broken away, exposing the formative alveolus of the penultimate molar (figs. 3 & 4, m_2) and the like cavity at an earlier stage of the last molar (ib. m_3). Provision has been made in this cavity for the lodgment of the anterior lobe of a tooth of equal transverse diameter (14 lines) with that of the tooth (m_3) in place and use in the largest examples of the present species. The dental canal (fig. 3, *o*) exposed by the hinder fracture presents a semielliptic form, 9 lines transversely and 3 lines from before backward. The canal undermines, as it were, the shell of the

* "On the Fossil Mammals of Australia, Part III. *Diprotodon australis*, Ow.," Philosophical Transactions, 1870, p. 571.

last formative alveolus, and it contracts as it inclines toward the outer wall of the ramus in its forward course.

The contour of the lower border of the ramus from the hind fracture to the symphysis (figs. 1 & 4, *e*, *s'*) is a more open curve than in the adult; it is feebly interrupted between the inflected border (*d*) and the hinder inflection or angle *a*; the slight concavity between *d'* and *a* being less apparent in the adult jaw. The ridges (fig. 1, *h*, *q*) bounding the ectocrotaphyte depression (*f*) are naturally feebler, less pronounced, in this young jaw; the base of the anterior one (*q*) rises from the transverse parallel of the hind lobe of the penultimate molar (m_2). The postinternal angle of the formative alveolus of the last molar appears to represent the postalveolar process of the mature mandible.

The oblique channel (answering to *u* in figures of the adult jaw) between the coronoid and postmolar processes here runs from that lodging the fore lobe of the penultimate molar to near the middle of the outer part of the interspace between the lobes of the antepenultimate molar (m_1); it thus preserves its general relative position to the last grinder "in place" and use, and doubtless was still more advanced when m_1 was "en germe."

Such changes in the relative position of parts, and differences of general shape, of the mandible in the adult and young Nototherе are dependent on, or concomitant with, the growth called for to sustain in action the full complement of teeth in the adult. No inference of specific difference can be deduced from the relative position of the hind part of the "symphysis mandibulæ" (*i*) in this young jaw to the front lobe of the second molar (d_4); because the socket of that tooth would move forward in the course of growth, whilst the symphysis extended its grasp of the fore parts of the two rami prior to the ultimate obliteration of the syndesmotic joint in the adult. At the present immature stage this articulation remains. The surface (fig. 4, *s**) is vertical, flat, with roughish rugæ, mostly directed from above downward and forward, gaining in prominence, through deepening of the intervals, along the lower third. It seems as if confluence had already begun at a small part of the upper and posterior border of the articular surface, such portion having been broken away from the left ramus and left adherent and seemingly confluent with the right one. Behind the lower part of the posterior border of the symphysis is the flattened, rough, slightly depressed surface (fig. 2, *v*) for muscular insertion noted in the older specimens.

The shallow indent or concavity dividing the inflected parts of the horizontal (*d'*) and ascending (*a*) rami has a more advanced position and a direction more approaching the horizontal than in the mature jaw: in Plate VI. fig. 4, *a*–*d'* is shown to be below the interval between the penultimate and last molars and parallel in extent with the contiguous lobes of these teeth. The inward extension of the bone at *a*, fig. 4, represents a resumption of the inflection of the lower margin of the jaw at its hinder part, from which resumption the bone thins off to be continued backward into the thickened part (*e*), which contributed to support the broken-off condyle.

This character is retained, but is better marked, in the adult mandible of *Nototherium Victoriæ* from South Australia (Plate VII.); but the incisor tooth in that species has a smaller and more advanced socket than in the present immature jaw, which in this more important character agrees with *Nototherium Mitchelli*.

In the removal of the part of the outer wall of the ramus in quest of a possible germ of a premolar or vertically replacing tooth, the base of the socket of the incisive tusk (Plate VI. fig. 5, *i**) was shown to extend beneath the first molar (d_3, *l*) as far as the septum, dividing the socket of that tooth from the next, lodging d_4.

The base of the incisive socket makes a feeble prominence at its upper and inner side at the hind third of the plate, sloping to the symphysial articular surface. The direction of the socket and of its contained incisor is that of the long axis of the symphysis.

The outlet of the socket (figs. 1 & 4, *s'*), 1 inch in advance of that of the foremost molar, is subquadrate, 7 lines in vertical and 6 lines in transverse diameter. The anterior outlet of the dental canal (fig. 1, 32) holds the same relative position as in the first described jaw of *Nototherium Mitchelli*.

The general depth of the present young jaw is of course much less, relatively to the crowns of the teeth in place, than in the adult.

I have been favoured by the Trustees of the Australian Museum, Sydney, with photographs and a plaster cast of the left ramus and back part of the symphysis of the mandible of a mature *Nototherium* from the freshwater deposits of Darling Downs.

It includes the series of five alveoli of its side, the last three of which support their teeth, which are rather more worn than in Mr. Hughes's specimen, and rather less so than in the mandible figured in Plate IV.

The longitudinal extent of the five alveoli is 6 inches 9 lines, as in Mr. Hughes's specimen; that of the last three molars is 4 inches 6 lines, but the hind talon of the last molar seems to have been broken away; were it entire, as in the first-described mandible, the three teeth would occupy an extent of 5 inches. The inner wall of the crown in each of the three molars has been broken away; but they appear to have equalled in breadth those teeth in the subject of Plate V., or the female mandibular specimen.

The inflection of the lower border of the jaw begins, as usual in the adult, on the vertical parallel with the socket of the last molar; the hind part of the symphysis extends to the vertical parallel with the fore part of the third molar (m_3).

The vertical diameter of the jaw below the last molar (m_3), taken at the outer wall of its alveolus, is 3 inches 2 lines; that taken at the third molar (m_1) is 3 inches 1 line.

At the fractured fore part of the cast is plainly shown part of the bottom of the socket of the left incisor, with its longitudinally striate and finely rugous surface. There is not enough of the cavity preserved to show that the missing part (almost the whole) of the socket and incisor differed in shape or direction from those in the subject of Plate IV. fig. 1, *i*.

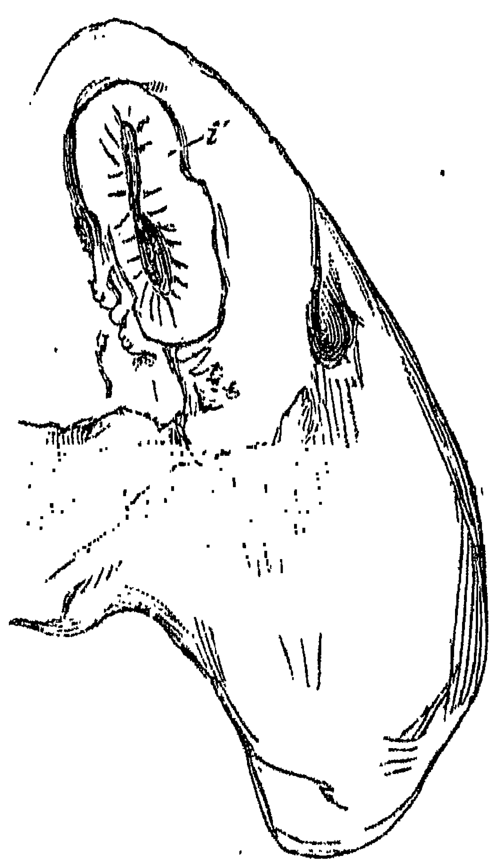
Agreeing, to the extent to which this cast does, with that of the more complete man-

dible of the inferred female of *Nototherium Mitchelli*, in every particular in which the comparison can be instituted, I am unable to point out any character whereby it can be referred to a different species; and I doubt whether a scrutiny of the original specimen would have supplied indications of such distinction.

Mr. KREFFT has favoured me with a pencil-sketch of the base of the incisor (Cut, fig. 2, *i*), of the natural size, from the original fossil, showing the exhaustion of the pulp in this tooth of limited growth.

B. *Nototherium Victoriæ*, Ow.—In the specimen of the left ramus of the mandible (Plate VII.), liberally transmitted for my examination by direction of the Trustees of the Museum of Natural History in Adelaide, South Australia, more of the ascending ramus is preserved than in any of the foregoing specimens; and there are differences which deserve to be interpreted as specific.

Fig. 2.



Fractured symphysis of jaw, with base of broken incisor, *Nototherium Mitchelli.*

The specimen was discovered by Mr. TILGATE, of Wentworth, South Australia, in freshwater deposits near Lake Victoria, in that colony.

The posterior orifice or entry of the dental canal (fig. 2, *o*) is on a level with the outlet of the last alveolus (m_3), not perforating the base of the coronoid above that level as in *Nototherium Mitchelli*. The inflection of the lower border (ib. d, d', d') begins on a vertical parallel with the hind lobe of the penultimate molar (m_2), and terminates a little behind the vertical parallel of the last alveolus, before the horizontal ramus bends upward into the base of the ascending ramus. After a subsidence for the extent of an inch and a half, the lower border again begins to be inflected, suddenly (at *a e*), and to a greater degree than at any part of the more posterior inflection in *Nototherium Mitchelli* (Plate V. fig. 1, *a*). The second inflection in the present species, at first as thick as the anterior one (viz. 5 lines), quickly thins off as it recedes to a plate of 1 line in thickness (*e*); which, after the course of about an inch, suddenly expands to form the thick inner part (*n*) of the broad posteriorly flattened hind surface of the ascending ramus, supporting the condyle (*c*). Much of this joint is broken away, but both the outer and inner beginnings of its base or "neck" remain, together with the entire extent of the base of the coronoid plate (fig. 1, *q*, *r*), the summit of which is also wanting. The concave platform (fig. 2, *u*) between the fore part of the coronoid process and the postalveolar ridge and process has a breadth of about an inch and a half; the process, as usual, has suffered fracture.

From the back part of the last alveolus to that of the base of the process is 1 inch 5 lines; from the same part to the dental orifice (*o*) is 2 inches 2 lines: the dental

canal runs obliquely forward; only the two anterior thirds of the orifice are defined by a sharp border; the diameter of the orifice is 4 lines. A groove (fig. 2, *p*) of the same breadth, and about an inch and a half in length, runs forward along the under and inner side of the orifice (*o*); this groove has a sharp inner border. A parallel ridge is directed from the back part of the dental orifice where it is broadest, backward, becoming narrower as it recedes, and subsiding an inch and a half from the orifice.

About 3 inches, following the curve, of the back part of the base of the coronoid (*r*, *f'*) are preserved; its commencement from the neck of the condyle (*r*) is raised much above the horizontal plane of the molar alveoli: the plate here is thin, but its margin is obtuse or rounded; at the hind part of the fracture (*f'*) it shows a thickness of 2 lines; as it advances it gains one of 3 lines; as the anterior border descends it gradually increases in thickness to 6 lines, near its obtusely rounded basal beginning. This (fig. 1, *q*), as usual, rises, buttress-like, from the outer wall of the mandible, on the transverse parallel of the middle of the last alveolus, and about an inch and a half lower than the outlet of that socket. The course of the base of the coronoid upward and backward is with a slight outward concavity at its anterior half, and is then level; its extent is 4 inches 9 lines; the anterior border of the process is gently convex, to the extent (4 inches) to which it has been preserved. The breadth of so much of the condyle (*c*) as is preserved is 2 inches 3 lines; the outer portion shows a small part of the articular surface, convex from before backward.

The ectocrotaphyte depression (fig. 1, *f*) is smooth and shallow; it is divided from the lower inflected part of the ascending ramus by a change of contour of the smooth outer surface, forming a broad convexity vertically; but this becomes, as it recedes, rather more prominent, thinner, and shows a roughened, as it were worm-eaten, surface (fig. 1, *h*), and, from a slight inflection at its termination towards the back surface of the ascending ramus, it there indicates the fore-and-aft extent of that part of the jaw as giving, viz. from the fore part of the base of the coronoid, 6 inches. It is possible that a smoother surface of the hind prominent outer and lower boundary of the ascending ramus may have suffered some abrasion in the fossil. There is no perforation of the crotaphyte

The symphysial end of the present ramus has been broken away at the fore part of the second alveolus, exposing part of the anterior root of that tooth (fig. 4, d_4), and a small part of the bottom of the incisor's socket (*i*).

The antero-posterior extent of the last three molar sockets is 4 inches 10 lines; a thin plate rises to form the outer wall of their outlets.

The inbending of the inner surface to form the hind part of the symphysis begins at the vertical parallel of the middle of the third molar (fig. 2, *s*, m_1). The lower part of the symphysis shows a pair of transversely crescentic insertional depressions, concave backward (fig. 3, *v*, *v*). The depth of the ramus at the interval between the third (m_1) and fourth (m_2) sockets is 2 inches 8 lines: in the female (?) of *Nototherium Mitchelli* it is 3 inches; in the male (?) it may attain 3 inches 10 lines.

The symphysial joint in *Nototherium Victoriæ* has become completely obliterated in the present full-grown specimen; a dense, minutely spongy tissue is included in a thin compact crust of bone.

The inner wall of the alveolar outlets does not rise so high as the outer one; it thins off to an edge closely fitting the contour of the base of the crown of the tooth; the inner side of the horizontal ramus (fig. 2) at once descends with a gentle vertical convexity, interrupted beneath the last and part of the penultimate sockets by the concavity due to the inflected lower border (*d*, *d'*). The depth of the inner side of the ramus behind the fifth (last) socket is 2 inches 9 lines; in *Nototherium Mitchelli* it is 3 inches 6 lines.

The portion of the base of the incisor-socket exposed by the anterior fracture (fig. 4, *i*) gives a vertical extent of 1 inch, a transverse breadth of 4 lines. The bottom is smooth; the side-walls worm-eaten, with a tendency to longitudinal striation. External to this part of the socket, about a line's distance, the dental canal is exposed, of a subcircular section, 3 lines in diameter; about the same thickness of the osseous tissue divides it from the outer surface of the jaw. Two inches behind this part a small orifice pierces the outer surface at the same distance below the middle of the outlet of the alveolus of the molar (m_1, fig. 1).

The colour of the fossil above described from the deposits near Lake Victoria is a rich brownish yellow. The osseous tissue is massive, the bone heavy, but does not adhere to the tongue. The minute cancelli are vacant, not filled up by mineral matter. The dental canal contains the easily displaced lacustrine deposit. The Nototherian fossils from Darling Downs are either of a deeper and duller brown colour, as in the first described jaw (Plate IV.), or of a greyish mottled stone-colour, as in the third and fourth speci-

C. *Nototherium inerme*, Ow.—The fossil (Plate VIII.) on which the species *Nototherium inerme* is founded consists of a left ramus of the lower jaw, mutilated and abraded as in most of the specimens from the river-beds and deposits of Queensland. The base of the coronoid (fig. 1, *f*), with the entry of the dental canal (fig. 3, *o*) and part of the inflected angle (ib. *b*, *e*), remain at the hind end of the specimen, and the back part of the symphysis (figs. 2 & 3, *s*) terminates the fore end. The symphysis does not extend backward beyond the vertical parallel of the fore half of the second molar (d_4). The dental canal (fig. 3, *o*) begins near the level of the molar, and 1 inch 9 lines behind the last alveolus. In the type mandible of *Nototherium Mitchelli*, as in the subjects of Plates IV. & V., the orifice of the dental canal is raised above the level of the grinders, and is 3 inches behind the last alveolus; yet the antero-posterior diameter of that alveolus is less in *Nototherium Mitchelli* than it is in *N. inerme*. The specific difference of *N. inerme* from both *N. Mitchelli* and *N. Victoriæ* is also shown in the relative position of the symphysis to the fully developed molar series. The absence of any trace of incisive alveolus at the fractured part of the symphysis indicates the tooth to have been relatively smaller, still less of the character of a tusk or weapon offensive or defensive;

whence the specific name originally suggested by the present fossil *. The depth of the horizontal ramus is relatively less than in *Nototherium Mitchelli*, and diminishes in a greater degree toward the symphysis. The vertical diameter at the back part of the symphysis is 2 inches in *Nototherium inerme*; in *N. Mitchelli* it is 2 inches 10 lines; yet the fore-and-aft extent of the four last alveoli is 6 inches in the former and 5 inches 7 lines in the latter, the same specimens which afford the difference of depth of ramus yielding the latter admeasurement.

The longitudinal extent in which the lower border of the ramus is inflected (fig. 3, *d*, *d'*) equals that in *Nototherium Victoriæ*; it is also interrupted at a similar part, but apparently less abruptly. The dental canal (fig. 3, *o*) perforates the smooth ridge or longitudinal rising of bone leading from the postmolar process toward the back part of the rising ramus, and, as in other *Nototheria* and in the *Diprotodon*, does not communicate with any canal leading to the outer surface of that ramus, as is the case in *Phascolomys* and the *Poëphaga*. The anterior outlet of the dental canal is below the position for the socket of the first molar (d_3), which socket would seem to be obliterated and the tooth shed earlier than in *Nototherium Mitchelli* or in *N. Victoriæ*. In the forward slope of so much as is preserved of the posterior margin of the ascending ramus and its uninterrupted continuation with the convex curvature leading to the symphysis, in the presence and position of the postmolar process, in the position of the base of the coronoid process exterior to the hindmost molar, in the thickness of the horizontal ramus and the convexity of its outer surface, the present jaw exemplifies its resemblance to that in *Phascolomys*; but it differs in the absence of the deep excavation on the outside of the ascending ramus, and in the inferior depth of the inner concavity due to the inferior extent of the inward production of the angle of the jaw, which marsupial character reaches its maximum in the smaller existing Poephagous and Rhizophagous families.

D. *Comparison of the Mandible.*—In comparing the mandible of *Nototherium* with that of *Diprotodon*, the chief difference relates, as might be surmised, to the chief dental one, viz. to the development, in the larger marsupial Herbivore, of the mandibular incisors into deeply implanted scalpriform tusks. The part of the jaw supporting and wielding these instruments is accordingly both deepened and widened in *Diprotodon*, and it is also, on an obvious mechanical principle, strengthened or rendered more massive by the presence of the pair of subsymphysial tuberosities †, of which there is no trace in *Nototherium*. The horizontal ramus in the smaller extinct genus is less deep in proportion to its breadth or thickness, and it loses depth at the symphysis instead of gaining it there, as in *Diprotodon* ‡. Consequently the lower contour of the horizontal ramus presents opposite curves in the two genera; it passes to the symphysis, describing a concavity in *Diprotodon* and a convexity in *Nototherium*. These differences are more

* 'Catalogue of the Fossil Mammalia &c. in Mus. Coll. Surg.,' 1845, p. 314.

† Philosophical Transactions, "On the Fossil Mammals of Australia," Part III. *tom. cit.* Pl. XXXV. fig. 2, *f*, *f*.

‡ Ibid. Pl. XXXV. fig. 1, *s*; and compare Pl. XLII. fig. 2, with Plate VIII. fig. 3 of the present Paper.

marked in the adult than in the young animals, becoming more conspicuous in *Diprotodon* as the incisive tusk acquires its adult proportions.

In all the Nototherian mandibles the lower border is inflected at two parts; the one in the horizontal portion, the other in the ascending portion, or "ramus." It may well be that this character, which is not present in Kangaroos and Wombats, may be presented by *Diprotodon*, when a perfect mandible of that animal is obtained; but if the fore part of the inflected border shown in the subject of Plate XLII. fig. 2 (Phil. Trans. 1870) be the beginning of an anterior inflection divided by a non-inflected tract from the posterior inflection, which represents the inflected angle in *Macropus* and *Phascolomys*, such beginning is more posterior in position, more nearly where the angular inflection begins in *Nototherium*. In the adult jaw of *N. Victoriæ* (Plate VII.) and in the immature one of *N. Mitchelli* (Plate VI.) the whole extent of the anterior inflection (*d*) is shown; only, in the adult specimen, the free border has suffered.

The orifice of the dental canal is raised to a level above that of the summits of the last molars in *Diprotodon*. The largest of the species of *Nototherium* differs little in this respect; but in *N. Victoriæ* and *N. inerme* the orifice is brought down to, or near to the level of the alveolar outlets. In the smaller existing herbivorous Marsupials it is placed still lower, being hidden in an excavation which does not exist in the extinct pouched herbivorous giants.

Of the position of the condyle we can speak only as it is indicated in *Nototherium Victoriæ*. Here it is raised high above the level of the molar series, as in all herbivorous Marsupials, but not so much raised relatively as in *Diprotodon*.

In the curve by which the coronoid process advances and rises from the fore part of the neck of the condyle, *Nototherium* resembles *Phascolomys* more than it does *Macropus*, in which the process rises in almost a straight line obliquely forward to its pointed apex.

§ 4. *Dentition*.—The dental formula of *Nototherium*, as of *Diprotodon*, is $i\,\frac{3-3}{1-1}$, $c\,\frac{0-0}{0-0}$, $m\,\frac{5-5}{5-5}=28$. The homologies of the molars with those of diphyodont Mammals are given by the symbols d_3, d_4, m_1, m_2, m_3, by which those teeth in the present paper will be signified as they range from before backward*.

The upper incisors, i_1, i_2, i_3 (Plate II. fig. 1, Plate III. fig. 3), follow one another in the same direction in each premaxillary, the foremost being the largest and the sole pair visible in a front view (Plate I. fig. 2). The right and left series run nearly parallel, slightly converging posteriorly; the greater interval between the right and left incisors of the second and third pairs is due to their smaller size, and their outer surface ranging with that of the larger exterior pair (Plate II. fig. 3, $_{22*}$). In the old *Nototherium Mitchelli* the first incisor does not project beyond an inch from the socket, the crown being

* In my Memoir on *Nototherium* (Quarterly Journal of the Geological Society, vol. xv. 1859), I state, in regard to those molars, that "the first appears to be a premolar and the rest true molars" (p. 171). I am now able to adduce [Plate VI. fig. 5] evidence that the first tooth is the homologue of d_3 in *Macropus*, and has no vertical successor $=p_3$.

directed downward very slightly forward and outward. The entire tooth (Plate IX. figs. 1 & 2) is 5 inches 1 line long in a straight line, 1 inch $7\frac{1}{2}$ lines in the greatest (fore-and-aft) diameter, which is about the middle of the root, 10 lines in greatest transverse diameter. The enamelled crown (ib. fig. 1, *c* and 1, *b*) is 1 inch in length, bevelled off, chisel-wise, from before upward and backward, and shows the partial application of enamel usual in such teeth: the free margin on the outer side of the crown (fig. 1, *b*) extends further back than that on the inner side (fig. 1, *c*), and is slightly everted; it is also thicker than on the even inner border. The breadth of the unenamelled back part of the crown at its base is $6\frac{1}{2}$ lines. Owing to the difference in extent of enamel on the sides of the crown, the abraded surface slopes from without inward and backward, as well as from before upward and backward. The enamel is $\frac{1}{4}$ of a line in thickness at the outer side of the crown; the whole outer surface is smooth. The crown is broadly convex anteriorly, rather flatter on the inner than on the outer side. The root is thickly covered by cement, and increases in every dimension, chiefly from before backward, as it recedes from the crown, until at a little below its mid length it attains the dimensions above given; it then diminishes to the pulp end. The outer side begins to be impressed by a longitudinal shallow channel about an inch and a half below the crown; and this channel increases in breadth, but not in depth, becoming, indeed, shallower near the pulp end of the root. On the inner side (fig. 1) the longitudinal channel begins somewhat nearer the crown, and sinks deeper as it recedes, besides becoming wider. The tooth is compressed and gently recurved, the front margin describing a greater convexity lengthwise than is the concavity of the hind margin; the root contracts to an antero-posterior diameter of 1 inch 3 lines; it is slightly excavated by the shallow remnant of the pulp-cavity (fig. 1, *a*). The breadth, owing to the opposite lateral channels, is least at the middle of this end, where it contracts to 3 lines; the part anterior to this gives a breadth of $4\frac{1}{2}$ lines.

Thus the first incisor in *Nototherium* differs from that in *Diprotodon* not only in size, both relative and absolute, in curvature, and in shape, but in structure or in kind. It is not scalpriform, not an ever-growing tusk with the enamel continued to the widely open base, but is a tooth of limited growth, consisting of a well-defined crown and fang. In this character the *Nototherium* resembles the Kangaroos, whilst the *Diprotodon* shows the Wombat or Rodent type of incisor.

Of the second and third incisors of *Nototherium*, nothing more is known to me than may be inferred from the sockets indicated in the cast of the skull now at Sydney. These seem to show that *Nototherium*, like *Diprotodon*, had them of similar and small size; the third not having its enamelled crown longitudinally extended and trenchant as in many Kangaroos. The longest diameter of the crown would appear to have been 6 or 7 lines.

Of the molars of the upper jaw I have, of *Nototherium Mitchelli*, the second, third, and fourth *in situ*, in a portion of the left maxilla; the same teeth (d_4, m_1, m_2), more worn, in a portion of the right maxilla of an older and larger Notothere; and the third

and fourth *in situ* in a fragment of the right maxilla of a younger specimen. The entire molar series of both sides is shown in the cast of the skull in the Australian Museum (Plates II. & III.), and the left series in the cast of the left maxilla of another individual, probably female. Photographs of both these specimens, now in the Museum of Natural History, Sydney, New South Wales, have been transmitted to me, with the sanction of the Trustees of the Museum, by the kindness of the able Curator, GERARD KREFFT, Esq., Corr. M.Z.S., &c.

Of *Nototherium inerme* I have the entire molar series of both sides of the upper jaw; and I infer, from a lithograph of "Australian Fossil Remains" sent me by Mr. KREFFT, that the Museum at Sydney possesses a similar specimen.

From these materials the characters of the upper molars of the present genus can be satisfactorily given.

The series of five molars in the entire skull [Plate II. fig. 1, Plate III. fig. 3 (reduced), Plate IX. figs. 3 & 4, nat. size] occupies an alveolar extent of 7 inches 2 lines; it describes a slight convexity downward and also outward, the right and left series converging anteriorly (Plate III. fig. 3) in a rather greater degree than in *Diprotodon*. The interval between the anterior lobes of the right and left last molars (m_3) is 2 inches 3 lines; that between the first small molars (d_3) is 2 inches. As in *Diprotodon*, the inner end of the front lobe of each two-ridged molar projects inward beyond the inner surface or contour of the antecedent tooth; but the hind lobe does not project so far beyond the level of the front lobe of the succeeding tooth as in *Diprotodon*.

The first upper molar (d_3) may be said to be two-lobed, but is divided in an opposite direction to that in the rest of the series; viz. into an outer and an inner, rather than a front and a back, lobe. The working-surface is subtriangular in form, the angles obtusely rounded, measuring in fore-and-aft extent 1 inch 1 line in the male *Nototherium Mitchelli* (Plate IX. figs. 3 & 4, d_3); the transverse diameter, posteriorly, is 11 lines. The outer lobe or division is the chief one, and constitutes the outer two thirds and the whole fore-and-aft extent of the tooth; the outer side of its base swells out like part of a cingulum or ridge; the summit is subcompressed, and seems to have been trituberculate; the inner and lower divisions consist of a larger hind tubercle and a smaller front one. On the whole, therefore, the tooth approaches the subsectorial type of its homologue in the Koala (*Phascolarctos*, Philosophical Transactions, 1871, p. 233, fig. 6, p_4); it is implanted by two roots, one behind the other, the posterior being the largest and grooved anteriorly, as if preparatory to further transverse subdivision.

The second molar (ib. ib. d_4) has a subquadrate working-surface, divided into two transverse wedge-shaped lobes (a, b), with an anterior (f) and a posterior (g) basal ridge; the latter is the thickest, and developes a small tuberosity at its outer end. This ridge is continued upon the outer and inner borders of the hind surface of the hind lobe, and further upon the outer than the inner one. A short ridge closes the outer and inner ends of the transverse valley. The antero-posterior diameter of the crown is 1 inch 1 line, as is likewise the transverse diameter of the broadest part of the tooth. The direction

of the summits of the two lobes is downward and a little forward; they run across the tooth rather more obliquely than in *Diprotodon* (Phil. Trans. 1870, Plate XXXVII. fig. 2, d_4), but with a similar curve of the apical ridge slightly concave backward. The less exposed enamel toward the bottom of the valley and near the basal ridges is punctate; but generally the enamel is smoother and more polished than in *Diprotodon*. This molar, like the rest of the upper ones, is implanted by two transversely disposed anterior roots (Plate IX. fig. 8), and one long transversely extended posterior root.

The third molar (Plate IX. figs. 3 & 4, m_1) has its ridges extended rather less obliquely than in d_4, but more so than in m_1 of *Diprotodon*. The antero-posterior diameter is 1 inch 4 lines; the transverse diameter 1 inch 3 lines. As the lobes are more entire they show better the curve of their summits, concave backward. The thicker anterior basal ridge (f) is continued at both ends upon the corresponding borders of the anterior lobe. The posterior basal ridge (g) is continued internally to the apex of the posterior lobe, gradually subsiding; externally it curves upon the end of the lobe, and subsides halfway to the summit.

The fourth molar (Plate IX. figs. 3 & 4, m_2) shows a diminution of breadth of the hind lobe in a greater degree than the corresponding tooth does in *Diprotodon*; its fore-and-aft extent is 1 inch 8 lines. The transverse breadth of the front lobe is, in the old male (fig. 7), 1 inch 7 lines; in the subject of fig. 4, 1 inch 6 lines; that of the hind lobe is 1 inch 5 lines. The inner end of each lobe is made thicker by a backward expansion, rather more marked in m_2 than in m_1.

In the last molar (Plate IX. figs. 3 & 4, m_3) the slightly abraded summits of the lobes show the more vertical or steeper slope of their fore side, which is convex transversely; also the transverse concavity of the hind side, due to the seeming backward bend, with thickening, of the outer and inner borders, and the curving slope of the hind part of the lobes, which gives them in profile a slight bend forward (fig. 3, m_3) as in *Diprotodon*.

The fore-and-aft extent of this tooth is 1 inch 8 lines; the breadth of the front lobe is 1 inch 7 lines; that of the hind lobe is 1 inch 3 lines; it contracts more rapidly to its summit than in *Diprotodon*. The posterior root of m_3 is slightly impressed lengthwise at its back part, and deeply so at its fore part.

The origin of the outstanding zygomatic process of the maxillary terminates posteriorly opposite, or on a vertical parallel with, the interspace between the third and fourth molars. In one large old Notothere (Plate IX. fig. 6) it extends, as before observed, a little further back; in an immature individual its origin hardly extends backward beyond the middle of m_1. This abutment against the upper molar alveoli is strengthened, as the hind molars take more share in the work of mastication. The base of the process stretches forward and upward as far as the parallel with the first alveolus.

A portion of the left upper maxillary of *Nototherium*, with d_4, m_1, and m_2, rather more worn than in the above-described specimen, exemplifies the same relation of the base of the malar rrocess of the maxillary with the alveoli of the three anterior molars.

In not any of the upper molars is the anterior basal ridge (f) so large relatively as in *Diprotodon.*

In the upper jaw of *Nototherium Mitchelli*, in which the last molar had recently come into place and the enamel had been slightly worn along the summit of the anterior ridge, the second molar showed the lobes worn down two thirds of the way toward the valley. In the cast of the right maxilla with the dentine exposed on the lobes of m_3, those of d_4 are worn down to the shallowest part of the valley. In the oldest specimen of this species the grinding-surface of this tooth (ib. fig. 7, d_4) is reduced to a smooth field of dentine (d) and osteodentine (o), with a peripheral boundary of enamel, e. This dental constituent does not exceed a line in thickness at this stage of abrasion.

The dentition of the upper jaw of *Nototherium inerme* is known to me by a portion of that jaw with the right and left series of grinders and much of the intervening bony palate; but the premaxillaries and upper incisors are wanting, being broken away with the contiguous part of the maxillary close to the molar (d_3); and both this and the second molar (d_4) are mutilated on the left side of the jaw. The right series is represented of the natural size in figure 5, Plate IX.

The first molar is relatively smaller and less complex on the grinding-surface than is d_3 in *Nototherium Mitchelli* (ib. fig. 4): the transverse and antero-posterior diameters are alike. The outer lobe or division has one coronal prominence upon which a slender triangular tract of dentine is exposed extended antero-posteriorly; a more equal-sided triangular tract is exposed on the shorter inner lobe; an anterior and a posterior basal ridge bound corresponding depressions divided by the confluence of the apices of the outer and inner divisions at the centre of the crown; a short external basal ridge closes the concavity impressed upon the hind half of the outer surface of the crown. One cannot distinguish, with certainty, the worn enamel from the dentinal tracts in the plaster cast of the answerable tooth of *Nototherium Mitchelli*; nor do the photographs help in this particular; but both concur in demonstrating the differences of size, shape, and proportion of the anterior molar, which I judge to exceed those allowed to sexual or individual variation, without affording ground for inferring generic distinction from the modifications of d_3, represented in Plate IX.

The more constant teeth (d_4–m_3) in figure 5 exemplify the Nototherian characters with the inferiority of size, corresponding with the little that is known of the present species. *Nototherium inerme*, like *Not. Mitchelli*, has the hind lobe of the last molar contracted in breadth, and the antero-posterior extent of the crown is less than that in the opposing molar (m_3) of the lower jaw.

A greater proportion of the enamel of this worn grinder, in the subject of fig. 5, Plate IX., shows the punctate rugous character than in the antecedent teeth.

The specific character of *Nototherium inerme* is well exemplified by the minor relative size of the anterior molar, d_3 (Plate IX. fig. 5), of the upper jaw, as by that of the incisor in the lower jaw.

Of the dentition of this jaw, I commence the description with those in that of the immature specimen of *Nototherium Mitchelli* (Plate VI.), consisting of the right ramus of the mandible with the first three molars in place, the germ of a fourth, and part of the formative cavity of a fifth molar. The tip of a procumbent incisor projects from a socket, close to the symphysis, where sufficient of the cavity was exposed to show that it expanded as it sank in the substance of the jaw.

Putting aside for awhile the evidence of the nature of this specimen afforded by others since received from Australia, I believe it may be of some interest and instructiveness to show how far its determination can be carried on the supposition that it is the sole example of its kind.

The mammalian character is seen at a glance by the complex crowns and rooted implantation of the molars, and by the simple condition of the ramus of the jaw, as of one piece of bone. The nonage of the individual to which the jaw has belonged is recognized at the same moment.

Of *Mammalia* corresponding in size with the parent of a young one having its newly cut milk-series of teeth in a jaw 8 inches long, the number of genera is not great; and we may be excused for thinking that most of those which are now represented by living species must be known. Of these we should be led at once to CUVIER's Pachyderms by the shape and size of the teeth of our young giant. The broad complex crowns of the molars show its herbivorous nature. The Tapir alone exhibits the bilophodont type of the second and third milk-grinders, with the conical, partly trenchant, partly crushing shape of the first; but it developes, with these in the mandible, eight small front teeth, of which the outermost pair are canines. A Rhinoceros of Sumatra or Java may show a pair of large tusk-like lower incisors, but they are associated, in the milk-dentition, with a smaller pair of mid incisors*.

There is another and more significant difference which the present fossil evidence of a large Herbivore presents in comparison with a specimen of the same age, or with the same phase of dentition, of any existing Herbivore. In the young Tapir, *e. g.*, with three deciduous molars in each mandibular ramus, and the germ of the next molar lying in its formative cavity deeper and less advanced than in the present fossil, the enamel has been worn from the summits of the first and second milk-molars so far as to expose the dentine, and it is abraded obliquely backward from the summits of both ridges of the third molar.

So also in a young Rhinoceros in which the second and third milk-molars are in place, the first and fourth being still "*en germe*," the enamel shows masticatory abrasion at the summits of the two chief lobes of d_2 and d_3. Corresponding signs of the assumption of vegetable nutriment in addition to that afforded by the mother's milk are visible in young Equines and Ruminants with a stage of molar dentition corresponding to that shown by the fossil under consideration.

Now, here, although the first, second, and third molars are well in place, and the

* OWEN's 'Odontography,' p. 591, pl. 138. fig. 15, *d i*, 1 & 2.

basal ridges of the fourth have risen to the brim of the socket, the enamel shows only a linear trace of attrition on the ridges of the second molar (Plate VI. fig. 3, d_4, h, g), with a very feeble trace on the anterior ridge of the third molar (ib. m_1); its hind ridge and the crown of the first molar (ib. d_3) are untouched. The inference is that the young Herbivore represented by the fossil derived a greater proportion of its nourishment from the mother, and much less from extraneous sources, than do the placental Herbivores at a corresponding stage of immaturity.

In this respect the fossil repeats the molar conditions of a young Kangaroo (*Macropus*) at the same phase of dentition†. With this phase the existing marsupial herbivore has attained that size and strength as a denizen of the pouch in which it begins to protrude its head to crop, occasionally, a tender leaf or blade of grass while the mother may be browsing or grazing. In the singleness and size of the sloping incisor, in the shape and proportion of the first molar (d_3), as well as in those of the second and third two-ridged grinders, d_4, & m_1, the fossil more closely resembles *Macropus* than any other known genus, whether marsupial or placental.

I accordingly here pushed the comparative research a stage further, and removed the outer wall of the jaw, as in fig. 5, Plate VI., to see if the large Australian bilophodont fossil carried its correspondence with *Macropus* to the extent of showing the germ of a premolar (p_3)‡: but of this tooth there was no trace. The length and deep implantation of the two fangs of d_3 (ib.), underlain by the expanded base of the procumbent incisor (ib. i*), make it very improbable that such germ of a p_3 could ever be developed in the species represented by the fossil.

Thus the results of the above comparisons, independently of other evidences of *Nototherium*, would have led to the conclusion that the young Herbivore, notwithstanding its bulk, belonged to a group of Mammals in which the milk-dentition was not so soon brought into use for grazing or browsing as in the Placental series; that it, therefore, was probably a Marsupial; which conclusion the close concordance in number and shape of grinding-teeth with the largest existing Herbivore of that order (the Kangaroo) would have put beyond doubt.

The lower incisor, in the immature example, had pushed its tip, as has been said, about two thirds of an inch from the socket; it is of a conical form, with an obtuse apex, which has been abraded for the extent of 3 lines (Plate VI. fig. 3, i'). The enamel coats the outer and under part of the tooth, bending up a little way upon the flat inner side, and in an increasing degree as the tooth expands (Plate VI. fig. 4, e): the enamel is not continued to the open base (ib. fig. 5, i*) as in *Diprotodon*: the line of termination is well defined. A thin layer of cement coats the rest of the tooth's circumference. The fracture of the exposed crown of the tooth gives a subquadrate surface, longest vertically, with the lower and outer angle rounded off. The two diameters are here

† OWEN, Art. "Teeth," Cyclopædia of Anatomy &c., fig. 594, B; and 'Anatomy of Vertebrates,' vol. iii. fig. 296, B.

‡ Philosophical Transactions, 1870, p. 539, fig. 4, p_3.

3 lines and 5 lines; but the vertical diameter of the hollow base exceeds an inch, the length of the entire though incomplete tooth being 2 inches 9 lines. It is directed obliquely forward and upward, at an angle of 140°, with the lower border of the ramus; a rather less open one than in *Diprotodon*.

The socket of the first molar (d_3) begins in this young jaw one inch behind the opening of that of the incisive tooth, which gives the length of the diastema (ib. fig. 1, *k*) at this stage of dentition. The first molar has an anterior and a posterior lobe. The front lobe is highest, and is a three-sided cone, with one angle in front and rather produced or ridge-like; it is subcanaliculate internally: the two posterior angles are continued into the fore and hind borders of the hind lobe; this is transverse, low, flat, inclined from behind forward and rather downward to the base of the front lobe. Both lobes are convex outwardly, and separated there by a shallow depression; the inner side of the tooth is much lower than the outer one. The fore-and-aft diameter of the crown is 9 lines, the transverse diameter posteriorly $6\frac{1}{2}$ lines; it is implanted by two fangs (ib. fig. 5, *l*), one behind the other, and each 10 lines in length; the entire length of the tooth, vertically, is 1 inch 6 lines.

The second molar (ib. d_4) assumes the two transversely ridged or bilophodont type, the lobes being in the form of transverse wedges. The anterior lobe is narrower transversely, broader from before backward than the posterior one. The anterior basal ridge (*f*) is a continuation of the slightly produced fore margins of the outer and inner sides of the front lobe, at their lower ends, into one another, defining below the slightly excavated surface on the fore part of the anterior lobe, the enamel of which is finely rugous. From the junction of the basal with the outer vertical ridge, a similar ridge is continued curving downward and backward, and then rising upon the posterior part of the outer surface of the front lobe (ib. fig. 1, *a*), defining upon that surface a finely rugous tract of enamel. The inner side of the front lobe (ib. fig. 4, *a*) has no such ridge. The hind surface of this lobe is less definitely bounded by a backward prominence of the outer border, and a slight vertical ridge or fold of enamel near the inner border. The valley (*h*) between the lobes has both the outer and inner entry crossed by a short ridge, the outer one being the strongest. The posterior basal ridge (*g*) is the broadest; its outer and inner ends bend up a short way upon the hind surface of the hind lobe. The line of initial abrasion at the edges of the two lobes is from above downward and backward. Both lobes present in profile a slight curve backward. The length (fore-and-aft diameter) of the tooth is 1 inch 2 lines; the breadth (transverse diameter) of the front lobe is 9 lines, that of the hind lobe is 11 lines. It is broader in proportion to its length than in *Diprotodon**. The anterior and posterior basal ridges are narrower, relatively, than in that genus.

The third molar (Plate VI., m_1) has the two lobes of equal breadth save at the summit, where this dimension rather exceeds in the hind lobe: the front lobe rises higher than the hind one. The front basal ridge is continued more abruptly from the anterior

* Philosophical Transactions, *tom. cit.* Plate XI. figs. 2 & 3, *d* 4.

angle of the inner border of the lobe than in d_4, and it passes outward to the base of the outer end of that lobe, like a "cingulum," without being continued upward into the outer prominence bounding that part of the front surface of the front lobe (fig. 3, m_1). This surface, as in the second molar, is finely rugous; it is concave transversely, convex vertically. The cingulum rises to a point, forming an angle upon the outer side of the base of the anterior lobe (fig. 1, m_1). The closing ridge of the valley is formed by its continuation backward from the angle, and is limited to the outer entry. The hind basal ridge (g) is thicker than in d_4.

The two lobes are not on the same parallel, but rather "*en échelon*," the hind one rising more mesially or internally, and its inner and fore angle looking forward clear of that of the other lobe. The unworn summits are more bent backward than in d_4. The fore-and-aft extent of m_1 is 1 inch 6 lines; the transverse diameter of the base of each lobe is 1 inch.

In the partially exposed calcified germ of m_2 (ib. figs. 3 & 4) the summits of the two lobes are not quite parallel, and the hind border of the hind lobe slopes more backward to a well-developed basal ridge.

The smooth shallow cavity behind the alveolus of m_2 is plainly the beginning of the formative chamber of m_3, calcification of which had probably not begun.

I regret not to possess specimens of *Nototherium* showing stages of mandibular dentition between that above described and the subject of Plate X. fig. 3.

This specimen forms part of a collection of fossils from the deposits of Darling Downs made by HENRY HUGHES, Esq., and now in the Museum of the Natural-History Society of Worcester, to the Council of which I am indebted for the opportunity of examining, comparing at the British Museum, and figuring instructive evidences of extinct Australian Mammals. The one which is referable to *Nototherium* is the right ramus of the mandible with the last three molars *in situ*, the fangs of the second and part of the alveolus of the first molar. The two fangs of the second molar (ib. d_4) show a fore-and-aft extent of at least 1 inch 2 lines for the crown of that tooth, with an extreme breadth of eight lines. That a still smaller tooth preceded it is indicated, as before remarked, by a part of its socket (d_3). The shape of that tooth, generically distinguishing *Nototherium* from *Diprotodon*, is instructively shown in the preceding specimen (Plate VI.). The antepenultimate tooth, or third counting backward (Plate X. fig. 3, m_1), measures 1 inch 6 lines in long diameter, and 1 inch 2 lines across the hinder lobe; the talon (g) at the back of this lobe is as well developed relatively as in the penultimate molar. The ridge (r) or production of the outer and front angle of the back lobe obliquely toward the middle of the front lobe is conspicuous at this stage of attrition; much of the front lobe has been broken away.

The crown of the penultimate molar (m_2) is in length 1 inch 8 lines, in breadth 1 inch 3 lines, in height 8 lines; the dentine is exposed at the summit of each ridge. The two ridges, or bilophodont type, of the molars of *Nototherium* were indicated rather than demonstrated in the specimens on which the genus was founded. The restoration

ventured on in the figures of these fossils* was verified by the molars in the immature jaw subsequently sent by LEICHHARDT. The first complete penultimate molar which I had the opportunity of studying showed the base of the crown girt by a "cingulum," developed behind into a low talon, and interrupted at the outer end and more so at the inner end of the two main lobes, and for a greater extent at the inner than at the outer sides: this character my present series shows to be constant.

The horizontal contour of the crown of the penultimate molar is rather rhomboidal than quadrate; for the hind lobe is more internal in position than the front one, and the ridges run, not in a line directly across the alveolar border, but from without inward and a little backward. The fore part of the outer end of each ridge is a little produced, most so in the hinder one, in which the produced part inclining inward, terminates or abuts below upon the middle of the base of the front ridge: the anterior part of the inner end of each ridge is a little produced forward, in an angular form; the general result is that the summit of each ridge is slightly concave forward, convex backward.

The enamel is for the most part smooth and polished; the delicate striæ of growth are well marked when viewed by a pocket-lens on the outer side of the tooth, and the same power brings into view a few punctations on the hinder slope of each ridge: the enamel is rather thicker on this slope than on the front one, and seems more so from being more obliquely abraded from before downward and backward: so exposed, the coronal surface of the enamel is a line in thickness; the tract of dentine abraded in the present tooth is two lines across. The hinder talon, or part of the cingulum, is most developed; the front one seems as if destroyed by pressure of that of the preceding molar.

Much of the crown of the last molar (ib. m_3) has been broken away; its base measures, in fore-and-aft extent 1 inch 10 lines, in transverse extent 1 inch $3\frac{1}{2}$ lines; this is at the anterior lobe, the posterior one is narrower. Each fang is longitudinally excavated at the surfaces next each other; and the outer part of the root, so defined, is thicker than the inner part.

The next stage of dentition which I have had the opportunity of observing in an original specimen of the present species corresponds with that of the maxillary teeth in the skull (Plate III. fig. 3); it is exemplified in the mandible which is the subject of Plate IV. The crown of the last molar (Plate X. figs. 1 & 2, m_3) is worn to within three or four lines of the transverse valley; those of the penultimate (m_2) and antepenultimate (m_1) molars show increasing degrees of attrition: the first and second molars are gone, but their sockets remain in the left ramus: the crowns are restored in outline, in fig. 1, from the subject of Plate VI.

The anterior fang of the first molar remains in the corresponding division of its socket: the fore-and-aft extent of the socket is 1 inch, being 3 lines more than in the young specimen (Plate VI. figs. 1 to 5, d_3). Now, as the roots of the first molar in that specimen are hollow shells of bone widening to their open base, the crown of the tooth

* "On the Extinct Mammals of Australia," Reports of Brit. Assoc. for 1844, p. 231, plate 3. fig. 1.

may gain increase of support, by enlargement of the fangs before they become solidified, as in the broken one in the present specimen. The difference of size may likewise be referred to difference of sex; it would be hazardous to predicate a difference of species on this ground. In both examples they come near, in size, to the anterior molar (d_3) in the upper jaw of *Nototherium Mitchelli.*

The socket of the second molar (Plate X. figs. 1 & 2, d_4) has a fore-and-aft extent of 1 inch 1 line, which accords closely with that in Plate VI. figs. 1–5, d_4).

The third molar (Plate X. figs. 1 & 2, m_1) shows both lobes abraded to their base; the enamel still crosses the valley, but that between the hind basal ridge and the hind lobe is worn away and a broad smooth expanse of dentine and osteodentine is exposed, 11 lines by 6 lines in diameter. The fore-and-aft extent of the remaining basis of the crown is 1 inch 6 lines; the breadth of the hind lobe is 1 inch. These dimensions accord sufficiently closely for specific identity with those of m_1, in the immature subject of Plate VI.

In m_2 (Plate X. figs. 1 & 2) the enamel of the hind lobe is worn down to the level of the hind basal ridge, which is partly abraded, but not down to the dentine. The narrower and lower anterior basal ridge is intact, and the enamelled crest of the anterior lobe rises 3 lines above it. The anterior productions (r, r) of the two lobes, rudimentally indicating the linking bars in certain Kangaroos, are instructively marked at the present stage of attrition. The posterior basal ridge of this tooth overlaps the anterior one of the next (m_3), the front lobe of which rises 5 lines above that level. The anterior prominence near the outer end of each lobe repeats the short forward angle in the contour of the enamel as here worn down. The corresponding prominence of the hinder lobe (r) inclines toward the middle of the valley; the macropodal affinity, slight as it is, is more strongly marked in *Nototherium* than in *Diprotodon**.

The fore-and-aft extent of m_3 is 1 inch 10 lines, exceeding by 2 lines that of the opposing molar above (Plate IX. fig. 4, m_3): in this, also, a macropodal character is repeated. The transverse extent of the front lobe of m_3, fig. 3, is 1 inch 4 lines; that of the hind lobe is less.

The entire extent of the lower molar series is 7 inches 2 lines, about 2 lines less than that of the upper molar series in the skull of *Nototherium Mitchelli* (Plate II. fig. 1).

In the series of sockets of the lower jaw of possibly the same individual, the partition between the fore and hind fangs of each tooth is much thicker than that between the sockets of distinct teeth. The transverse space between the hind lobes of the right and left last lower molars is 2 inches 9 lines; between the front lobes of the first molars 1 inch 5 lines. Each mandibular series describes a very slight curve as it advances forward, with the convexity outward. The base of the socket of the incisor, which does not extend beyond that of the first molar, is 1 inch 2 lines in vertical diameter, 8 lines in transverse diameter.

In the specimen of the mandible with the symphysis entire, or nearly so (known to

* Compare figures 11 & 18, Plate XI. Philosophical Transactions, 1870, with figures 1, 2, & 3 in Plate IX.

me by the cast, Plate V.), the molars show almost the same stage of attrition as in the preceding specimen. The first and second molars are retained on the left side. The crown of the first (d_3) is worn down to a flattened uniform surface, showing the same posterior breadth as in the entire crown in the immature jaw. The two roots supporting it have now risen nearly half an inch above the socket. The dimensions and proportions of the following four grinders closely accord with those in the mandible, the teeth of which are figured of the natural size in Plate IX. fig. 3.

In the part of the right ramus of *Nototherium Mitchelli* with the three last molars and the back part of the symphysis, the molars are worn nearly to the same degree: their antero-posterior extent is 5 inches 2 lines. The left ramus of the same species, more mutilated anteriorly, but with a greater proportion of the ascending branch, shows the last two molars similarly worn. The enamel in these Nototherian specimens is as thick as in *Diprotodon*.

In a mandibular fragment with the lobes of the last molar worn down to the valley, the anterior root of the penultimate molar is exposed, showing a strong curve convex forward, with a deep anterior longitudinal indent almost dividing the implanted end (Plate X. fig. 8). The fine rugosity of the cement, repeated on the closely clasping wall of the socket, is here well shown.

The molars (Plate X. figs. 4, 5, 6) in the mandible of *Nototherium Victoriæ* (Plate VII.) show nearly the same stage of attrition as in the Worcester specimen of *N. Mitchelli* (Plate X. fig. 3).

As already stated, they are limited to the last three teeth and a fragment of the one in advance. In m_1 the ridge closing the outer entry of the valley (h, figs. 4 & 5) developes an enamel tubercle; and there is a smaller one at the inner entry (h', fig. 6). Of this there is no trace in the perfect specimen of that molar in the immature jaw of *Nototherium Mitchelli* (Plate VI.), and only a very feeble indication of such on the outer side. The rudiment of the "link" or ridge (r) from the hind lobe to the middle of the base of the hind surface of the front lobe is well marked in *N. Victoriæ*. The hind talon (g) closely overlaps so as to interlock with the front talon (f) of the penultimate molar, m_2. The abraded surfaces of the two lobes slope from before downward and backward. The fore-and-aft diameter of m_1 is 1 inch 6 lines.

The fore part of the penultimate molar (fig. 4, a, m_2) rises half an inch above the overlapping talon (g) of the antecedent tooth, at the outer and inner ends of which the front talon of m_2 appears. Externally it curves up to terminate near the base of the fore and outer part of the front lobe; on the inner side it sooner subsides. The greater breadth, as compared with m_1 of the front lobe, is gained chiefly by extension of the inner part. A ridge, beginning at the back part of the outer end of the front lobe, curves down to the outer entry of the valley, developes there a tubercle, and curves up the outer side of the hind lobe, whence a similar ridge curves downward and backward to the hind talon; the middle and thickest part of this is undermined by the smooth surface which overlies the front talon of the last molar (f, m_3).

The fore-and-aft extent of m_2 is 1 inch 9 lines; the transverse breadth of the front lobe is 1 inch $2\frac{1}{2}$ lines, that of the hind lobe is 1 inch 1 line. The abraded surfaces of the summits of these lobes slope, as in m_1, in the same direction but in a greater degree. The hind root of m_2 is exposed by the fracture shown in figs. 1 & 2, Plate VII.; it inclines somewhat backward as it sinks in the socket; its basal breadth at the outlet of the socket is 1 inch; it contracts, in the same direction, to 7 lines; much of its surface shows minute granulate longitudinal striations.

The last molar (Plate X. figs. 4, 5, 6, m_3) rises above and projects inwardly beyond the preceding, in the same degree as m_2 does in relation to m_1. The festoon character of the ridges curving toward the outer entry of the valley and to the hind talon is repeated in greater strength; the outer closing tubercle (fig. 4, *h*) is less marked than in m_1, but is conspicuous, as is that in the ridge closing the inner entry (fig. 5, *h'*). I incline to regard these tubercles as constant, and as differentiating the last two molars of the present species from those of *Nototherium Mitchelli*. A mere linear tract of dentine is exposed on the obliquely worn apices of the transverse ridges of m_3. The fore-and-aft diameter of this molar is 1 inch 10 lines; the transverse extent of the abraded summit of the hind lobe is 10 lines, but that of its base is $13\frac{1}{2}$ lines, the same diameter of the front lobe being 15 lines. The enamel in *Nototherium Victoriæ* is not so thick as in *N. Mitchelli*; its surface is similar.

When the skull, or upper jaw, of this species may be found in South Australia, it will yield, as in the case of the Queensland specimen, the characters ascribed by MACLEAY to *Zygomaturus*, with, probably, better marked specific characters than those of the lower jaw.

No mandible or mandibular teeth, referable or adaptable to those of the maxilla in the unique subject of Plates II. & III., have yet been discovered, save those which yield the characters of the genus *Nototherium*. No skull adaptable to the mandible and mandibular teeth of *Nototherium* has yet been discovered, save that to which the name *Zygomaturus* was given. The admission, therefore, into palæontological catalogues of two genera of bilophodont *Marsupialia* of the bulk of *Nototherium* awaits the discovery of fossils demonstrating the distinctive characters of such.

Taking a retrospect of the dental characters of the genus *Nototherium* with reference to a comparison with those of the genus *Diprotodon*, we find that the indications, few and feeble though they seemed in the mutilated mandibles and mandibular dentition first received*, have been supported and the inferences therefrom verified in a striking and unexpected degree by the characters of the rest of the skull and of the maxillary dentition.

The first molar, for example, does not give, in miniature, the bilophodont character of the other and larger molars; its crown answers rather to the outer half of the two-ridged grinder with a rudiment of the inner half of the hinder transverse ridge or lobe.

* *Op. cit.*

This tooth, in fact, exemplifies the final stage of modification converting the longitudinally trenchant type of the premolar in existing Carpophagous and Poëphagous Marsupials into the crushing character shown in the homologous tooth of the larger marsupial Herbivores. The rest of the molar series in *Nototherium* differs from that in *Diprotodon* by the smaller size and in the smoother enamel; and, perhaps, in a little stronger indication of the production of the hind part, near the inner end, of the transverse lobes, especially of the front one.

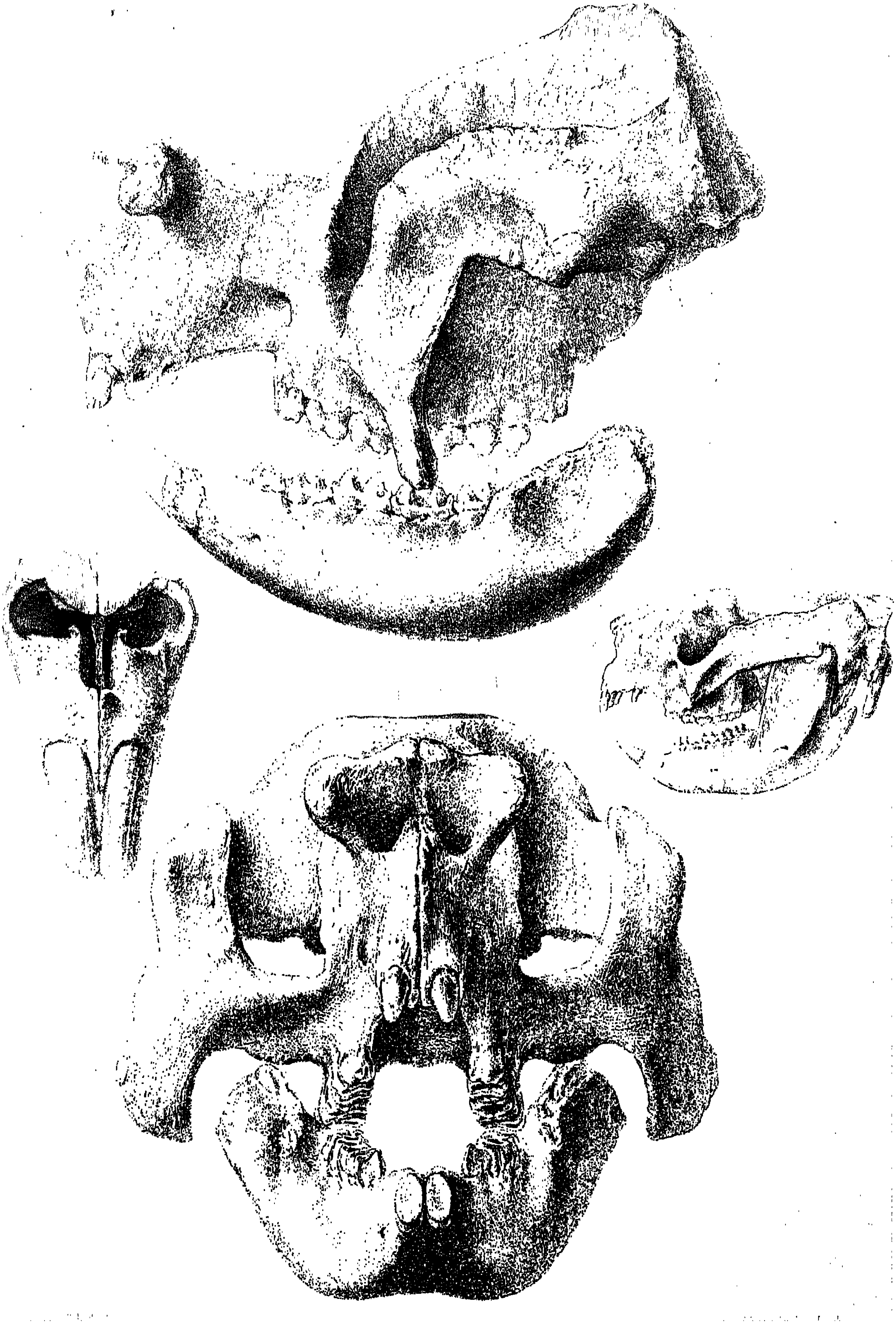
In the incisor series the generic character of *Nototherium* is strongly marked by the form, structure, and nature of the front upper incisor, as before described: and in this character we see a nearer approach of *Nototherium* to *Macropus*, while the characters of the front upper incisor in *Diprotodon* approximate that genus to *Phascolomys*. But in the number and disposition of the upper incisors, as in the bilophodont molars of limited growth, both the large extinct genera retain the poëphagous character, as contradistinguished from the rhizophagous modification shown by the Wombats among the existing marsupial Herbivores.

The lower incisor of *Nototherium* shows more of the scalpriform character, at least in the young individual, than does the upper one; but, in the full-grown animal, this tooth is far from having the proportions and depth of implantation which make it resemble, in *Diprotodon*, the lower pair of scalpriform teeth of the Wombats. In *Nototherium* the lower incisor differs from that in *Diprotodon* in being narrower, with the enamel continued less far or high upon the inner side: this tooth in the young specimen increases more rapidly as it sinks in the socket; but this may be a repetition of an immature character, which is shown, in a minor degree, in the jaw of the young *Diprotodon* described and figured in a former Paper*. The widely open base of the growing incisor does not, however, extend backward beyond the first molar; and as this part contracts and solidifies in the adult, the base of the tooth and its socket are moved more forward, and in one species of Notothere (*N. inerme*) to the anterior half of the symphysis in advance of the roots of the first molar.

I have described, in former works, some detached bones† which from their size might, and probably do, belong to the genus *Nototherium*; but I have since received evidence of extinct species of nearly equal size, and more nearly akin to the Wombat and Kangaroo families, to which some of the fossil limb-bones from Nototherian localities might possibly belong. I may venture to state that the olecranon of *Nototherium* is as little produced as in the ulna of *Diprotodon*. But I deem it better to defer further illustrations of the osteological character of the present genus until the discovery of some portion of the skeleton, under circumstances of juxtaposition, which would warrant such further communication to the Royal Society.

* Philosophical Transactions, 1870, p. 533, Pl. XLIII. fig. 5, *i*.

† An astragalus, *e. g.*, in "Report on the Extinct Mammals of Australia," *op. cit.* p. 233, plate 5. figs. 1–6.



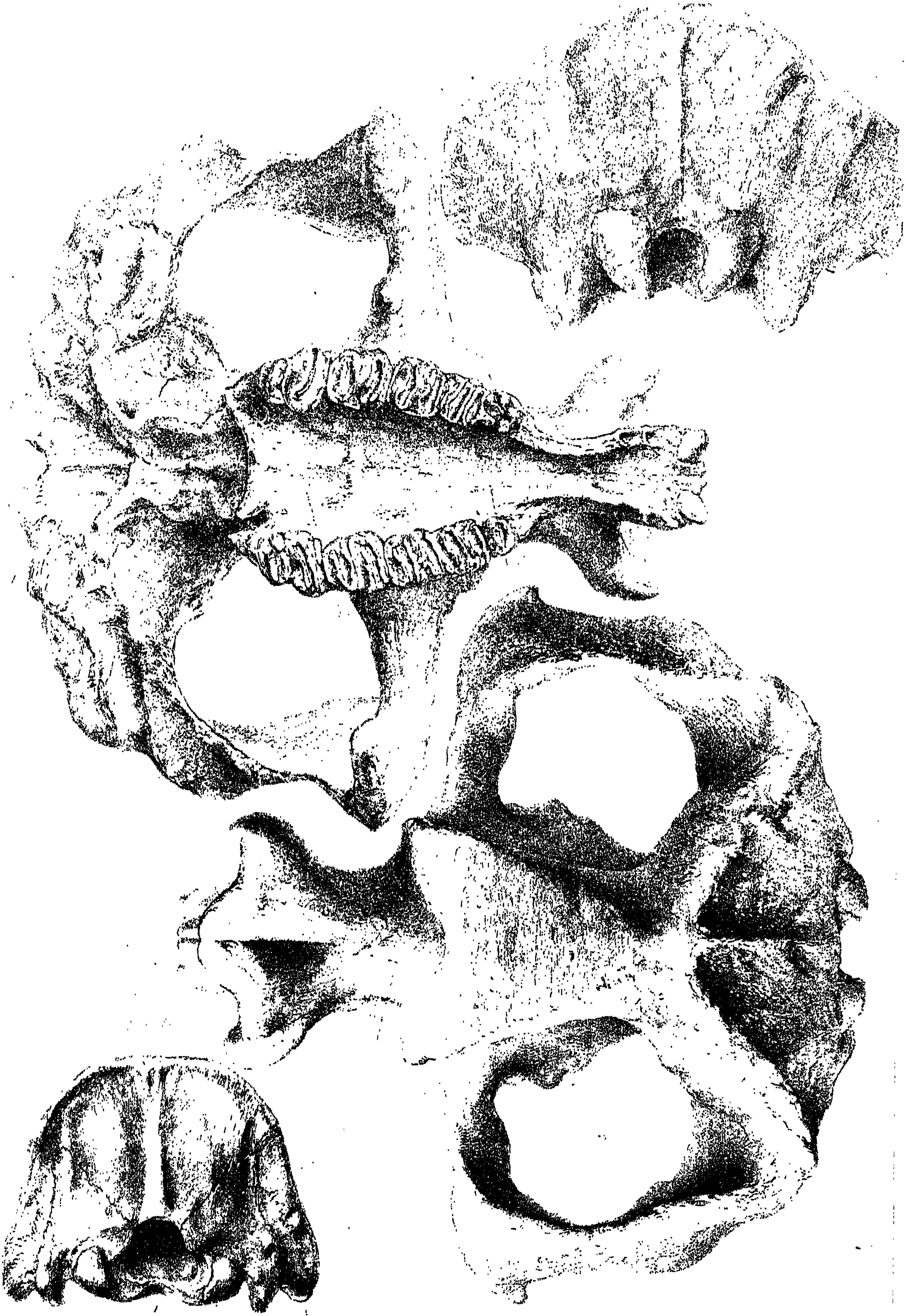


Table of Localities of *Nototherium*, showing:—

Where found.	By whom.	Date.
Freshwater deposits, Darling Downs, Queensland	Sir Thomas Mitchell, C.B.	1842
„ „ Ib. ib. „	Ludwig Leichhardt, M.D.	1845
„ „ King's Creek „	Mr. Turner*	1846
„ „ Gowrie „	Henry Hughes, Esq.	1856
„ „ King's Creek „	Fred. Neville Isaac, Esq.	1856
„ „ Eton Vale „	Edward S. Hill, Esq.	1863
Breccia-cavern, Wellington Valley, New South Wales....	[illegible]	1869
Freshwater deposits, near Lake Victoria, South Australia	[illegible]	1869
„ „ King's Creek, Queensland	[illegible]	1870
„ „ Gowrie Creek „	[illegible]	1870
„ „ Worra-worra Station „	[illegible]	1871
„ „ Jimbour „	G. M[illegible], Esq.	1871
„ „ Chinchilla Station „	G. [illegible]	1871
„ „ Queensland	H.R.H. the Duke of Edinburgh, K.G. ..	1871

Description of the Plates.

PLATE II.

Fig. 1. Side view of skull of *Nototherium Mitchelli*:—one third nat. size.
Fig. 2. Front view of skull of *Nototherium Mitchelli*:—one third nat. size.
Fig. 3. Side view of skull of *Phascolarctos fuscus*:—one half nat. size.
Fig. 4. Front view of naso-premaxillary end of skull of *Phascolomys latifrons*:—nat. size.

PLATE III.

Fig. 1. Back view of cranium of *Nototherium Mitchelli*:—one third nat. size.
Fig. 2. Upper view of skull of *Nototherium Mitchelli*:—one third nat. size.
Fig. 3. Under view of skull of *Nototherium Mitchelli*:—one third nat. size.
Fig. 4. Back view of skull of *Phascolomys platyrhinus*:—three fourths nat. size.

PLATE IV.

Fig. 1. Oblique side view of mandible of *Nototherium Mitchelli* (male?):—half nat. size.
Fig. 2. Upper view of the same mandible and teeth:—half nat. size.
Fig. 3. Under view of the same mandible:—half nat. size.

* "In 1845 or 1846, Mr. Turner, Superintendent of a Sheep-station on the Condamine, brought to Sydney a large collection made by himself after various 'freshets' or floods in the creeks of the river had left the fossils bare and protruding from the sides of the gulleys; he disposed of them to a Mr. Benjamin Boyd, a merchant, who soon after got embarrassed; he sent the fossils to Europe for sale, but suffered our Museum to take casts of all of them."—Letter from W. S. Macleay, Esq., F.R.S., to the author, dated 9th March, 1858. The lower jaw of *Nototherium Mitchelli* (Plate IV.) formed part of this collection, which was purchased for the British Museum.

PLATE V.

Fig. 1. Side view of mandible of *Nototherium Mitchelli* (female?):—half nat. size.
Fig. 2. Under view of the same mandible:—half nat. size.
Fig. 3. Upper view of the same mandible and teeth:—half nat. size.
Fig. 4. Front view of symphysis and broken incisors of the same mandible:—nat. size.
Fig. 5. Back view of part of rising ramus of the same mandible:—nat. size.

PLATE VI.

Fig. 1. Outer side view of right mandibular ramus and teeth of a young *Nototherium Mitchelli.*
Fig. 2. Under view of the same ramus.
Fig. 3. Upper view of the same ramus and teeth.
Fig. 4. Inner side view of the same ramus and teeth.
Fig. 5. Outer side view of fore part, with alveoli of the incisor and of the first two molars exposed, of the same ramus.

All the figures are of the natural size.

PLATE VII.

Fig. 1. Outer side view of part of mandibular ramus and teeth of *Nototherium Victoriæ*:—half nat. size.
Fig. 2. Inner side view of the same ramus and teeth:—half nat. size.
Fig. 3. Under view of back part of symphysis of the same ramus:—nat. size.
Fig. 4. Front view of fractured symphysis of the same ramus:—nat. size.

PLATE VIII.

Fig. 1. Outer side view of mutilated right mandibular ramus and teeth of *Nototherium inerme*:—half nat. size.
Fig. 2. Upper view of mutilated mandible and teeth of *Nototherium inerme*:—half nat. size.
Fig. 3. Inner side view of mutilated left mandibular ramus of *Nototherium inerme*:—half nat. size.
Fig. 4. Fractured surface of the symphysis:—two thirds nat. size.

PLATE IX

Fig. 1. Side view of first incisor, upper jaw, of *Nototherium Mitchelli.*
Fig. 1 *a*. Base of the same tooth.

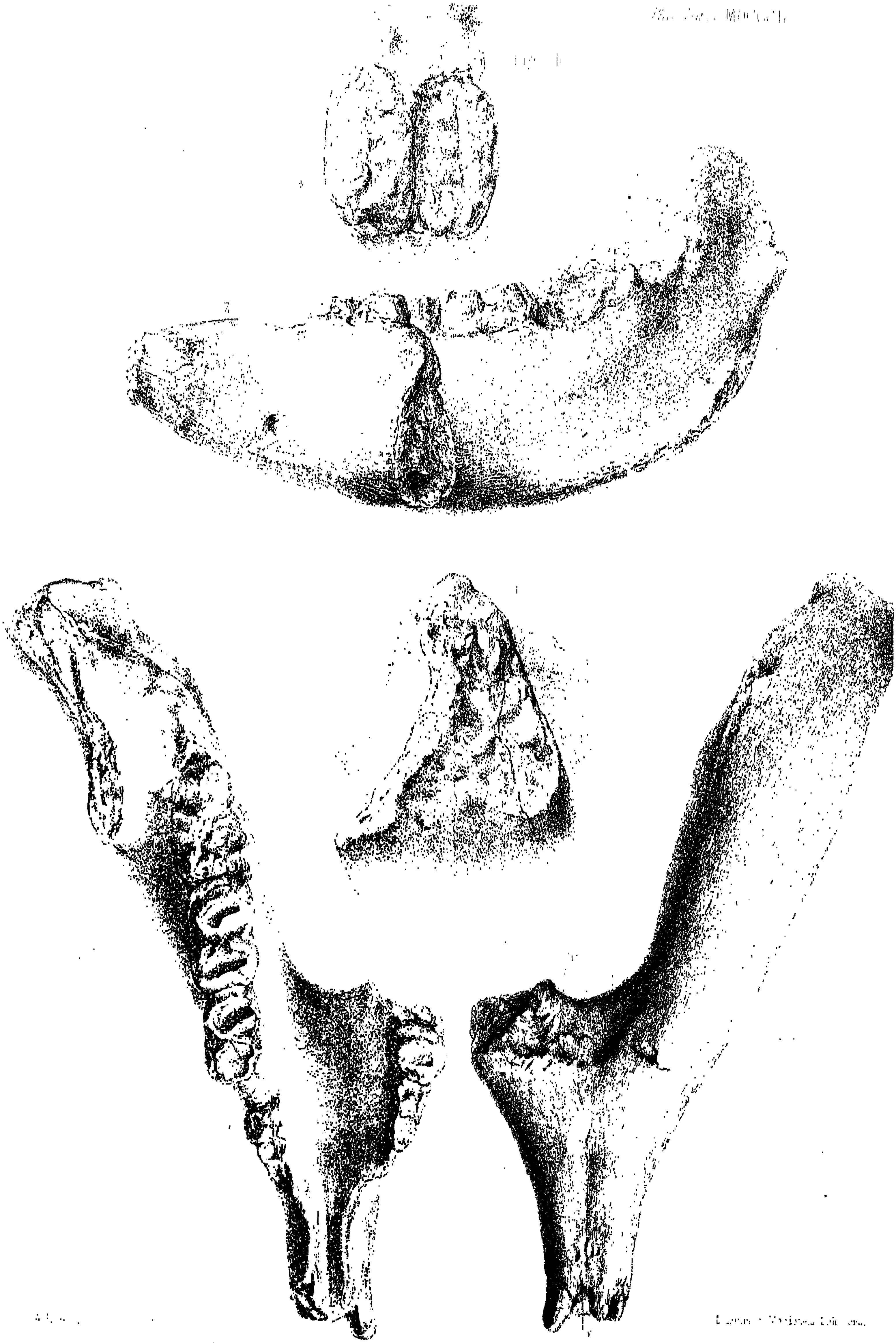
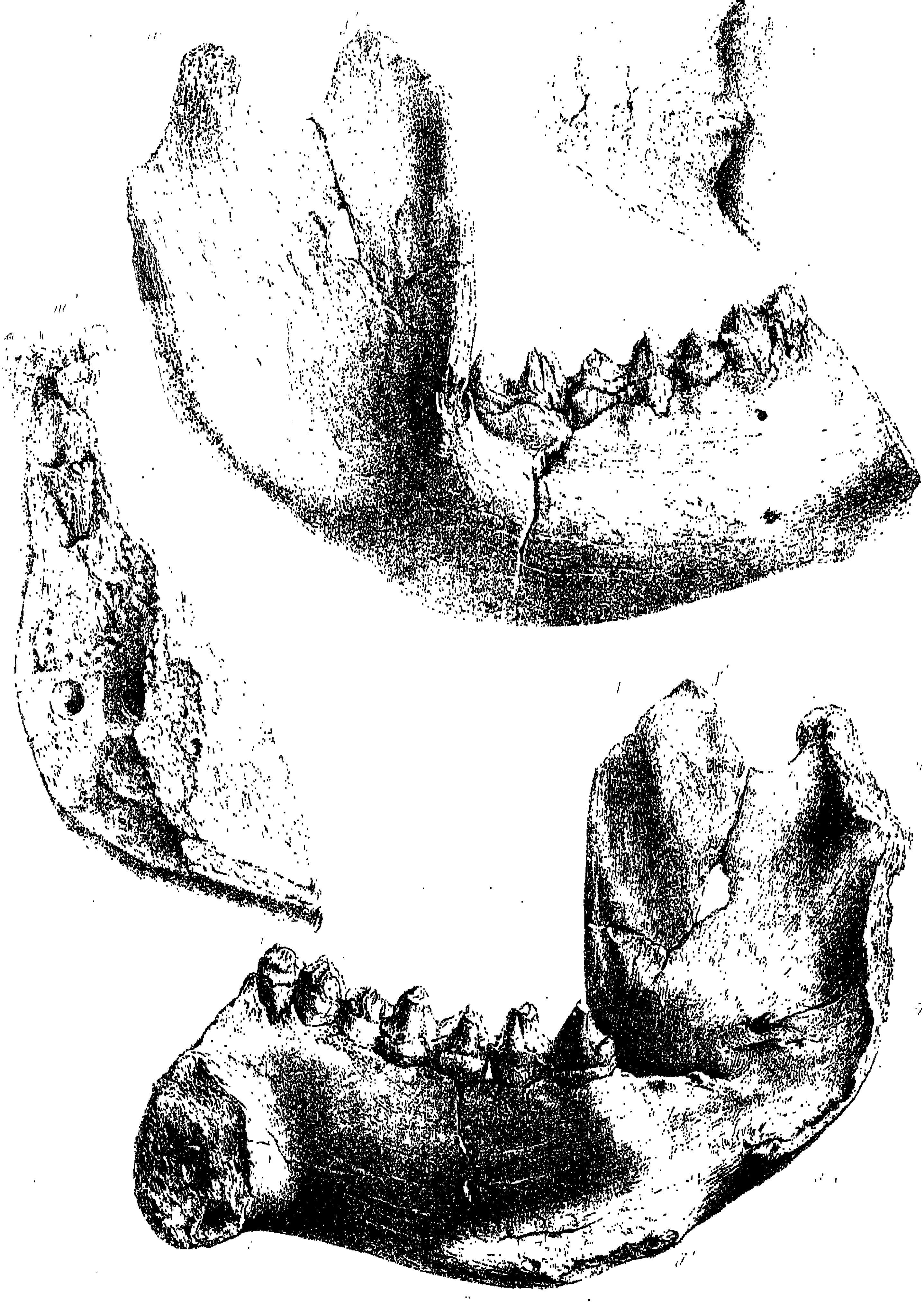
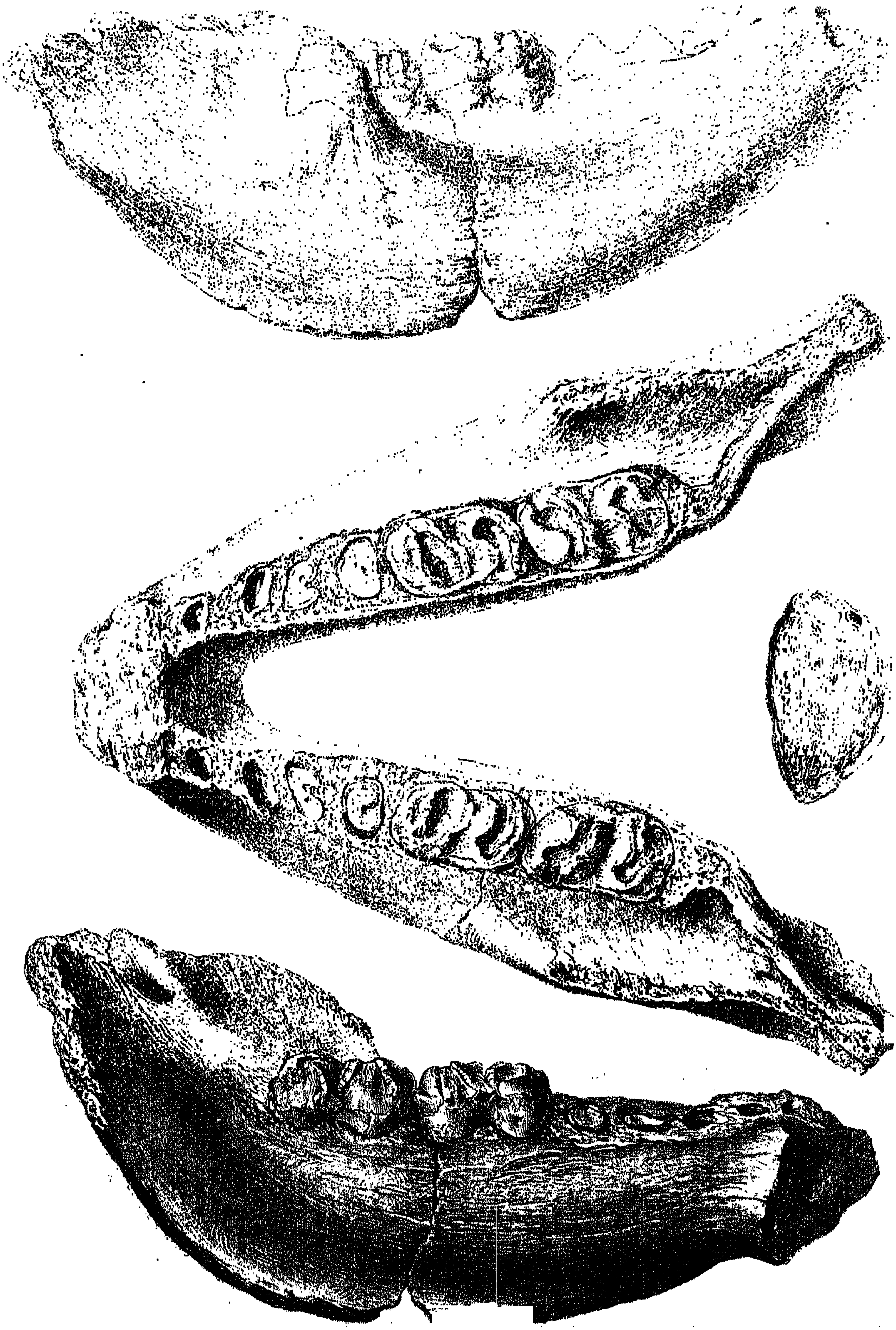


Fig. 1





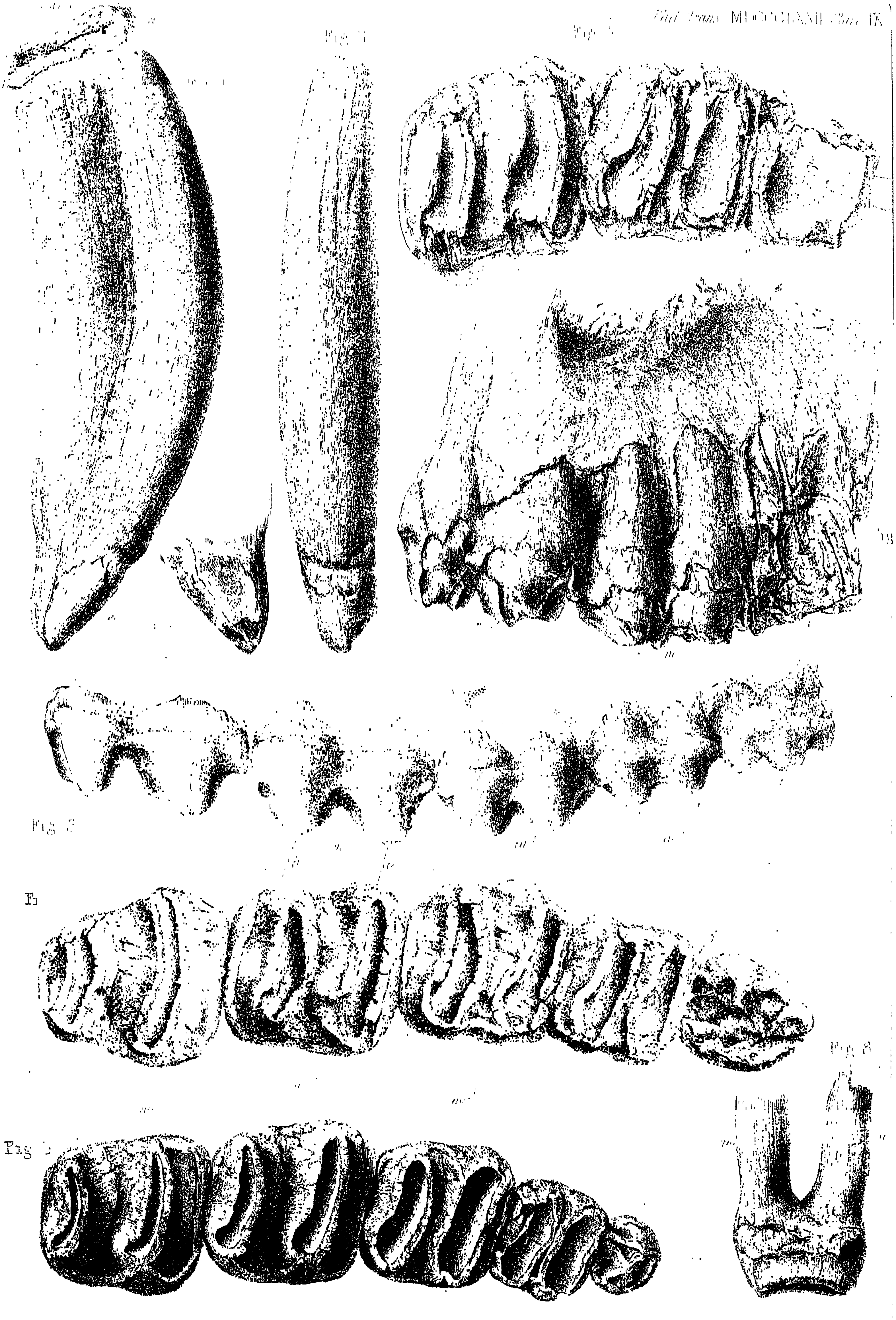


Fig. 2
Fig. 3
Fig. 8

Fig 3.

Fig 1.

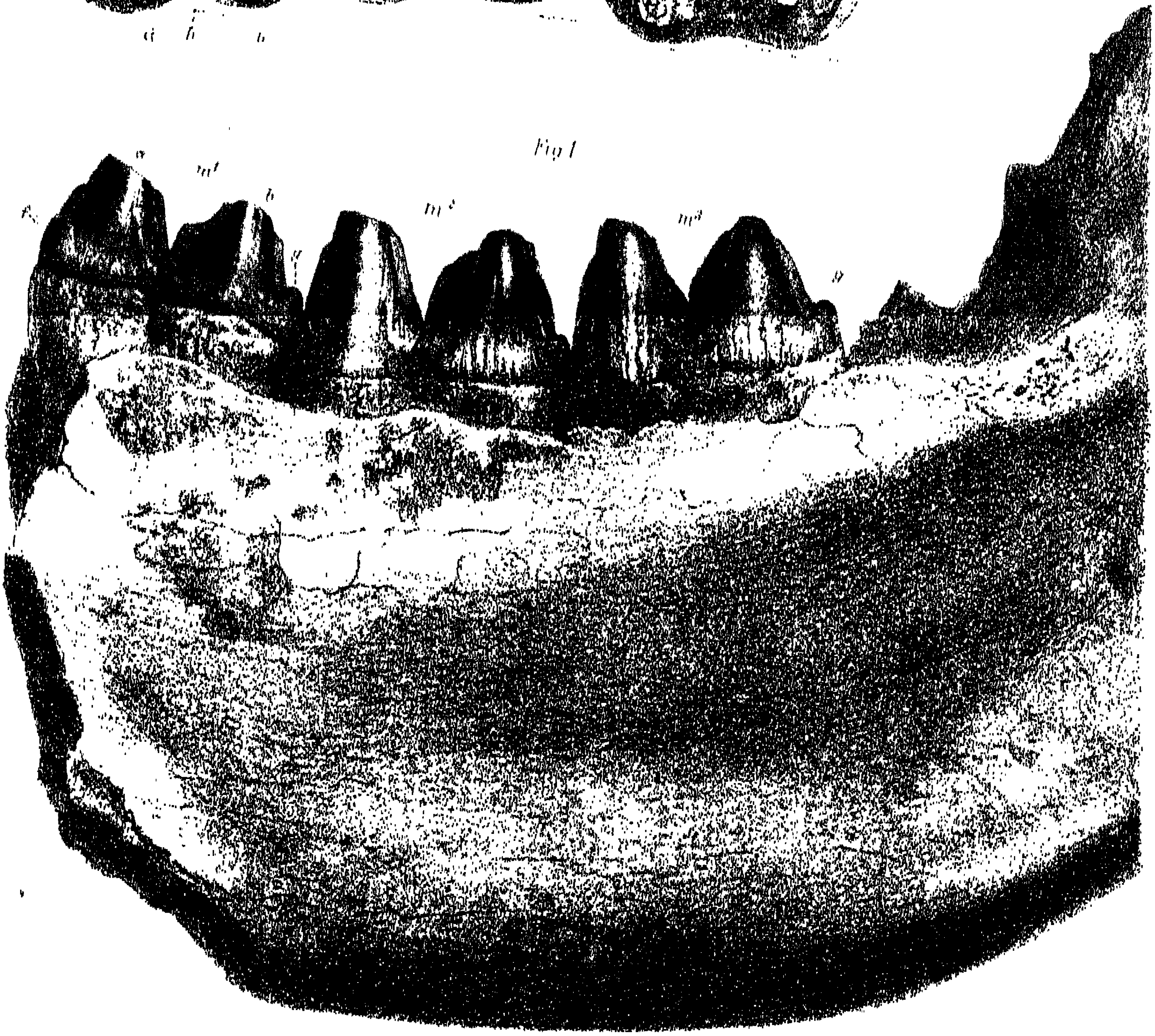


Fig 2.

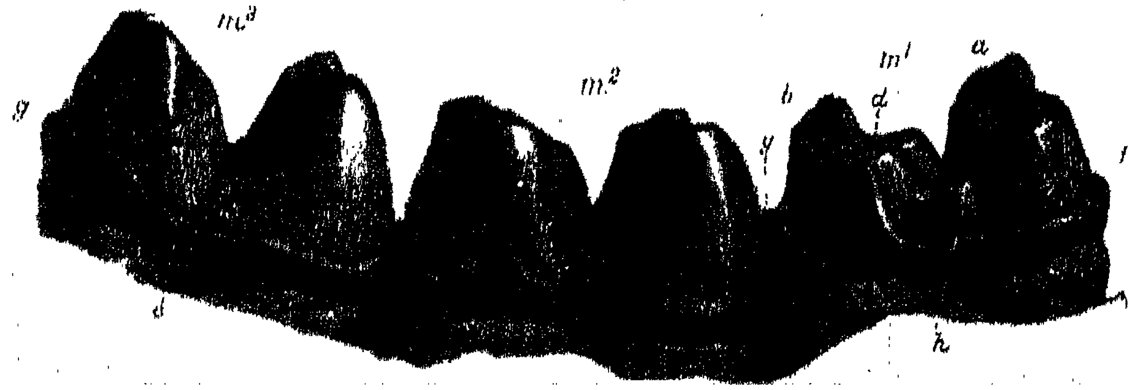


Fig. 1 *b*. Side view of crown of the same tooth.
Fig. 2. Front view of the same tooth.
Fig. 3. Outer side view of the right upper molars of *Nototherium Mitchelli* (male?).
Fig. 4. Grinding-surface of the same teeth.
Fig. 5. Grinding-surface of the right upper molars of *Nototherium inerme*.
Fig. 6. Outer side view of a portion of the right maxilla, with three molars (d_4, m_1, m_2) *in situ*, of *Nototherium Mitchelli* (old male?).
Fig. 7. Grinding-surface of the same molars.
Fig. 8. Front view of an upper molar (m_1), with the two anterior roots exposed.

All the figures are of the natural size.

PLATE X.

Fig. 1. Outer side view of right lower molars of *Nototherium Mitchelli* (male); the worn crowns of d_3 and d_4 are restored in outline.
Fig. 2. Grinding-surface of the last three teeth of the same jaw, with outlines of that of d_3 and d_4.
Fig. 3. Grinding-surface and parts of right lower molars of *Nototherium Mitchelli* (female?).
Fig. 4. Outer side view of the last three lower molars (m_1, m_2, m_3), with the mutilated hinder half of the second (d_4), of *Nototherium Victoriæ*.
Fig. 5. Grinding-surface of the same teeth (of d_4 only the hinder half is preserved).
Fig. 6. Inner side view of the same teeth.
Fig. 7. Back view of the penultimate lower molar, with the hind fang exposed *in situ*, of *Nototherium Mitchelli*.
Fig. 8. Roots and remnant of crown of a much-worn lower molar of *Nototherium Mitchelli*.

All the figures are of the natural size.

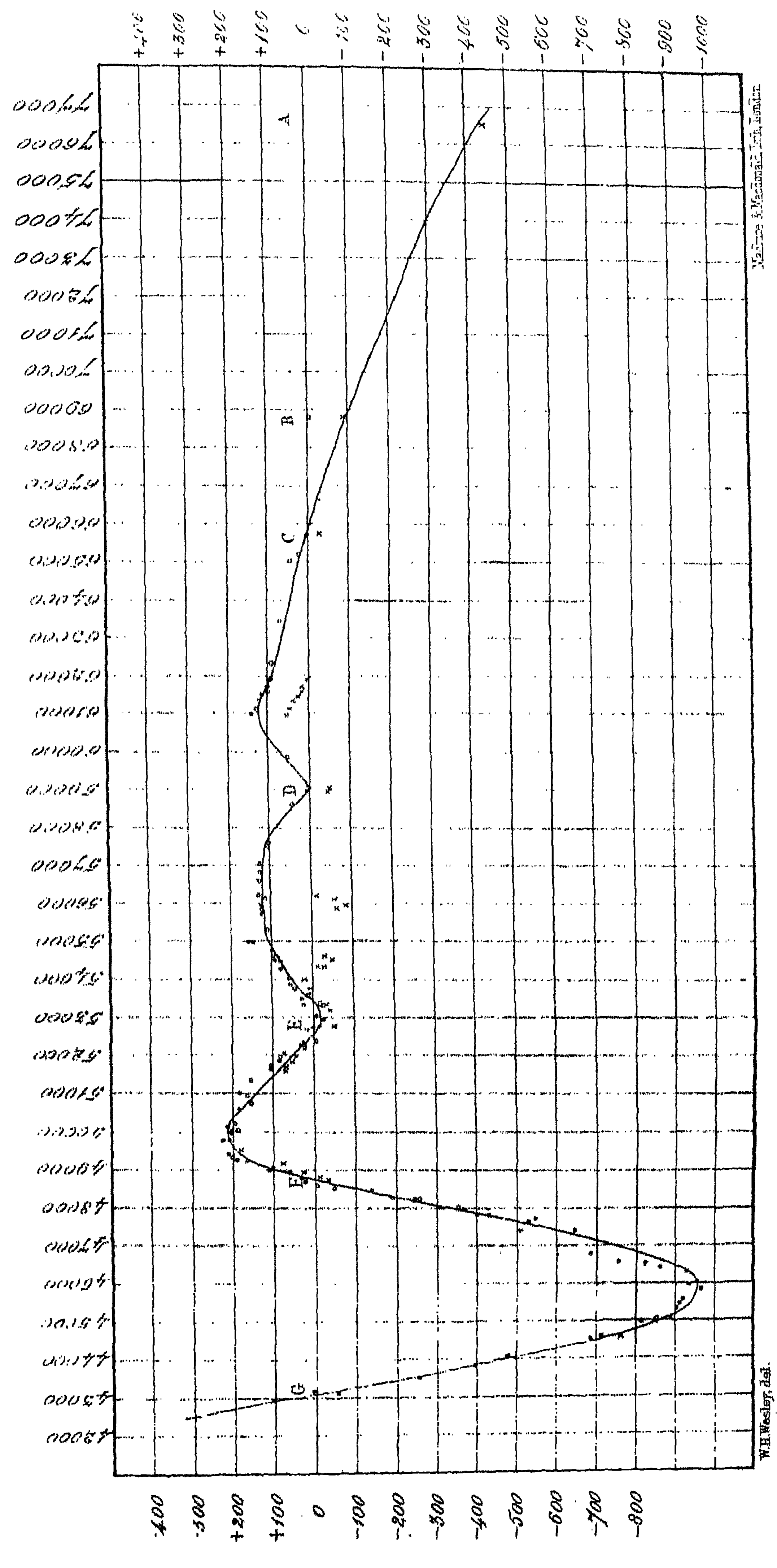
PLATE XI.

Fig. 1. Portion of mandible with three last grinders ($m_{1,2,3}$) of *Nototherium Mitchelli*; inside view: nat. size.
Fig. 2. Outside view of the grinders of the same jaw.
Fig. 3. Upper view or working-surface of the same grinders.

[Since the foregoing pages were in type, the Trustees of the British Museum have received, as a Donation from His Royal Highness the Duke of Edinburgh, K.G., the specimen which forms the subject of the above Plate, which the Council of the Royal Society have ordered to be added to the illustrations of the present paper. The fossil, obtained by His Royal Highness in the Province of Queensland, Australia, is part of

the collection of interesting and instructive specimens brought home from the Circumnavigatory Voyage of Her Majesty's Ship 'Galatea,' under the command of His Royal Highness, and exhibited in the South Kensington Museum. The molar teeth in this fossil are in a more perfect state of preservation than in any other Nototherian jaws which had previously come under my observation; and, being from an individual of the same age as that to which the jaw and teeth of *Nototherium Victoriæ* from South Australia belonged, they exemplify more plainly and completely the differential characters of that species and of the *Not. Mitchelli* from the Province of Queensland.

The teeth ($m_{1, 2, 3}$) of *Nototherium Mitchelli* differ from those of *Not. Victoriæ* in the presence of a "cingulum" on the outer side of their base (comp. figs. 2 & 3, *c*, Plate XI. with figs. 4 & 5, Plate X.). In m_1 the cingulum is continued from the prebasal ridge (fig. 2, *f*) along the base of the anterior lobe to the outer tubercle (*h*), closing the valley, upon the outer surface of which the cingulum subsides; but it resumes its course behind the tubercle along the outer side of the posterior lobe (*b*), where it is continued upward along the middle of that side; but from the base of this vertical prominence (*d*, fig. 2, Plate XI.) the cingulum is continued to the postbasal ridge (*g*), which, like the prebasal one, is a more developed part of the cingulum. In *Nototherium Victoriæ* the cingulum is represented only by the pre- and postbasal ridges (Plate X. figs. 4, 5, 6, *f*, *g*), and by the closing tubercles (ib. *h*, *h'*) before mentioned (p. 77), at the outer and inner ends of the transverse valley. The penultimate molar (m_2, Plate XI.) presents the same differential characters. In m_3 of the present specimen of *Nototherium Mitchelli* the vertical continuation from the cingulum upon the outer side of the hinder lobe is not present (Plate XI. fig. 2, m_3); but in *Not. Victoriæ* the outer closing tubercle (Plate X. fig. 4, m_3, *h*) and the postbasal ridge (ib. *g*) are both extended, converging, to curve up along the outer side of the hinder lobe of m_3, without crossing its base, as does the cingulum (Plate XI. fig. 2, m_3, *c*) in *Not. Mitchelli*. All the molars in *Not. Victoriæ* differ from those in *Not. Mitchelli* by the greater breadth or thickness of the postbasal ridge.—July 23, 1872.]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W.H.Wesley, del.

V. *Corrections and Additions to the Memoir on the Theory of Reciprocal Surfaces* (Philosophical Transactions, vol. clix. 1869). *By Professor* CAYLEY, *F.R.S.*

Received July 22,—Read November 16, 1871.

1. I AM indebted to Dr. ZEUTHEN for the remark that although the "off-points" and "off-planes," as explained in the memoir, are real singularities, they are not the singularities to which the θ, θ' of the formulæ refer. The most convenient way of correcting this is to retain all the formulæ with θ, θ' as they stand, but to write ω, ω' for the number of "off-points" and "off-planes" respectively; viz. we thus have

ω, off-points,
θ, unexplained singular points,

and

ω', off-planes,
θ', unexplained singular planes,

the formulæ as they stand, taking account of the unexplained singularities θ and θ', but not taking any account at all of the off-points and off-planes ω, ω'. The extended formulæ in which these are taken into account are:—

$$\begin{aligned}
a(n-2) &= \kappa - B + \rho + 2\sigma + 3\omega, \\
b(n-2) &= \rho + 2\beta + 3\gamma + 3t, \\
c(n-2) &= 2\sigma + 4\beta + \gamma + \theta + \omega, \\
a(n-2)(n-3) &= 2(\delta - C - 3\omega) + 3(ac - 3\sigma - \chi - 3\omega) + 2(ab - 2\rho - j), \\
b(n-2)(n-3) &= 4k + (ab - 2\rho - j) + 3(bc - 3\beta - 2\gamma - i), \\
c(n-2)(n-3) &= 6h + (ac - 3\sigma - \chi - 3\omega) + 2(bc - 3\beta - 2\gamma - i).
\end{aligned}$$

which replace SALMON's original formulæ (A) and (B).

2. In the formulæ

$$\begin{aligned}
q &= b^2 - b - 2k - 3\gamma - 6t, \\
r &= c^2 - c - 2h - 3\beta,
\end{aligned}$$

it is assumed that the nodal curve has no actual multiple points other than the t triple points, and no stationary points other than the γ points which lie on the cuspidal curve; and similarly that the cuspidal curve has no actual multiple points, and no stationary points other than the β points which lie on the nodal curve; and this being so, q is the class of the nodal curve and r that of the cuspidal curve. But we may take the formulæ as *universally* true; viz. q may be considered as standing for $b^2 - b - 2k - 3\gamma - 6t$, and r

as standing for $c^2-c-2h-3\beta$.; only then q and r are not in all cases the classes of the two curves respectively.

3. In the formulæ No. 6 *et seq.*, introducing the new singularity ω, we have as follows:—

$$(a-b-c)(n-2) \qquad =(\varkappa-\text{B}-\theta+2\omega)-6\beta-4\gamma-3t,$$
$$(a-2b-3c)(n-2)(n-3)=2(\delta-\text{C}-3\omega)-8k-18h-12(bc-3\beta-2\gamma-i);$$

and substituting these in $n'=a(a-1)-2b-3c$, and writing for n' its value $=a(a-1)-2\delta-3\varkappa$, we have, as in the memoir,

$$\begin{aligned} n'=n(n-1)^2-n(7b+12c)+4b^2+8b+9c^2+15c \\ -8k-8h+18\beta+12\gamma+12i-9t \\ -2\text{C}-3\text{B}-3\theta; \end{aligned}$$

viz. there is no term in ω.

Writing $(n-2)(n-3)=a+2b+3c+(-4n+6)$ in the equations which contain $(n-2)(n-3)$, these become

$$\begin{aligned} a(-4n+6)&=2(\delta-\text{C})-\ a^2-4\varrho-9\sigma-2j-3\chi-15\omega, \\ b(-4n+6)&=\ 4k\ \ -2b^2-9\beta-6\gamma-3i-2\varrho-j, \\ c(-4n+6)&=\ 6h\ \ -3c^2-6\beta-4\gamma-2i-3\sigma-\chi-3\omega, \end{aligned}$$

(SALMON's equations (C)); and adding to each equation four times the corresponding equation with the factor $(n-2)$, these become

$$\begin{aligned} a^2-2a&=2(\delta-\text{C})+4(\varkappa-\text{B})-\sigma-2j-3\chi-3\omega, \\ 2b^2-2b&=4k-\beta+6\gamma+12t-3i+2\varrho-j, \\ 3c^2-2c&=6h+10\beta+4\theta-2i+5\sigma-\chi+\omega. \end{aligned}$$

Writing in the first of these $a^2-2a=n'+2\delta+3\varkappa-a$, and reducing the other two by means of the values of q, r, the equations become

$$\begin{aligned} n'-a&=-2\text{C}-4\text{B}+\varkappa-\sigma-2j-3\chi-3\omega, \\ 2q+\beta+3i+j&=2\varrho, \\ 3r+c+2i+\chi&=5\sigma+\beta+4\theta+\omega. \end{aligned}$$

The reciprocal of the first of these is

$$\sigma'=a-n+\varkappa'-2j'-3\chi'-2\text{C}'-4\text{B}'-3\omega';$$

viz. writing $a=n(n-1)-2b-3c$, and $\varkappa=3n(n-2)-6b-8c$, this is

$$\sigma'=4n(n-2)-8b-11c-2j'-3\chi'-2\text{C}'-4\text{B}'-3\omega';$$

and it thus appears that the order σ' of the spinode curve is reduced by 3 for each off-plane ω'.

4. As to the other two equations, writing for ϱ, σ their values, these become

$$j+6t+3i+5\beta+6\gamma=b(2n-4)-2q,$$

$$2\chi+3\omega+4i+18\beta+5\gamma=c(5n-12)-6r+3\theta,$$

equations which admit of a geometrical interpretation. In fact, when there is only a nodal curve, the first equation is

$$j+6t=b(2n-4)-2q,$$

which we may verify when the nodal curve is a complete intersection, $P=0$, $Q=0$; for if the equation of the surface is $(A, B, C\between P, Q)^2=0$, where the degrees of A, B, C, P, Q are $n-2f$, $n-f-g$, $n-2g$, f, g respectively, then the pinch-points are given by the equations $P=0$, $Q=0$, $AC-B^2=0$, and the number j of pinch-points is thus

$$=fg(2n-2f-2g)=(2n-4)fg-2fg(f+g-2);$$

but for the curve $P=0$, $Q=0$ we have $t=0$, and its order and class are $b=fg$, $q=fg(f+g-2)$, or the formula is thus verified.

Similarly, when there is only a cuspidal curve, the second equation is

$$2\chi+3\omega=c(5n-12)-6r+3\theta,$$

which may be verified when the cuspidal curve is a complete intersection, $P=0$, $Q=0$; the equation of the surface is here $(A, B, C\between P, Q)^2=0$, where $AC-B^2=MP+NQ$, and the points χ, ω are given as the intersections of the curve with the surface $(A, B, C\between N, -M)^2=0$.

Now $AC-B^2$ vanishing for $P=0$, $Q=0$ we must have $A=\Lambda\alpha^2+A'$, $B=\Lambda\alpha\beta+B'$, $C=\Lambda\beta^2+C'$, where A', B', C' vanish for $P=0$, $Q=0$; and thence $M=\Lambda M'+M''$, $N=\Lambda N'+N''$, where M'', N'' vanish for $P=0$, $Q=0$. The equation

$$(A, B, C\between N, -M)^2=0,$$

writing therein $P=0$, $Q=0$, thus becomes $\Lambda^3(N'\alpha-M'\beta)^2=0$; and its intersections with the curve $P=0$, $Q=0$ are the points $P=0$, $Q=0$, $\Lambda=0$ each three times, and the points $P=0$, $Q=0$, $N'\alpha-M'\alpha=0$ each twice; viz. they are the points $2\chi+3\omega$.

But if the degree of Λ is $=\lambda$, then the degrees of N', M', α^2, $\alpha\beta$, β^2 are $2n-3f-2g-\lambda$, $2n-2f-3g-\lambda$, $n-2f-\lambda$, $n-f-g-\lambda$, $n-2g-\lambda$, whence the degree of $\Lambda^3(N'\alpha-M'\beta)$ is $=5n-6f-6g$, and the number of points is $=fg(5n-6f-6g)$, viz. this is

$$=fg(5n-12)-6fg(f+g-2),$$

or it is $=c(5n-12)-6r$; so that θ being $=0$, the equation is verified.

5. It was also pointed out to me by Dr. ZEUTHEN that in the value of $24t$ given in No. 10 the term involving χ should be -6χ instead of $+6\chi$, and that in consequence the coefficients of χ are erroneous in several others of the formulæ. Correcting these,

and at the same time introducing the terms in ω, and writing down also the terms in θ as they stand, we have

$$
\begin{aligned}
4i &= \ldots - 2\chi + 3\theta - 3\omega,\\
24t &= \ldots - 6\chi + 9\theta - 9\omega,\\
2\sigma &= \ldots \qquad\quad\; - \theta - \omega,\\
8\varrho &= \ldots + 6\chi - 9\theta + 9\omega,\\
8\varkappa &= \ldots - 6\chi + 17\theta - 25\omega,\\
2\delta &= \ldots + 6\chi - 9\theta + 15\omega,\\
8n' &= \ldots - 30\chi + 21\theta - 45\omega,\\
c' &= \ldots - 12\chi + 10\theta - 20\omega.
\end{aligned}
$$

The equations of No. 11, used afterwards, No. 53, should thus be

$$
\begin{aligned}
4i + 6r &= (5n-12)c - 18\beta - 5\gamma - 2\chi + 3\theta - 3\omega,\\
-24t - 8q + 18r &= (-8n+16)b + (15n-36)c - 34\beta + 9\gamma + 4j - 6\chi + 9\theta - 9\omega\,;
\end{aligned}
$$

and from these I deduce

$$44q + \tfrac{63}{2}r = (44n-88)b + (\tfrac{105}{4}n - 63)c - \tfrac{409}{2}\beta - \tfrac{633}{4}\gamma - 132t - 87i - 22j - \tfrac{21}{2}\chi + \tfrac{63}{4}\theta.$$

6. In No. 32 we have (without alteration) $\theta=16$; but in the application (Nos. 40 and 41) to the surface $FP^2+GR^2Q^3=0$ we have $\theta=0$, and there are $\omega=fpq$ off-points, $F=0$, $P=0$, $Q=0$, and $\chi=gpq$ close-points, $G=0$, $P=0$, $Q=0$. The new equations involving ω are thus satisfied.

7. I have ascertained that the value of β' obtained, Nos. 51 to 64 of the memoir, is inconsistent with that obtained in the "Addition" by consideration of the deficiency, and that it is in fact incorrect. The reason is that, although, as stated No. 53, the values of two of the coefficients D, E may be assumed at pleasure, they cannot, in conjunction with a given system of values of A, B, C, be thus assumed at pleasure; viz. A, B, C being $=110$, 272, 44 respectively, the values of D, E are really determinate. I have no direct investigation, but by working back from the formula in the Addition I find that we must have $D=\frac{477}{4}$, $E=315$; the values of the remaining coefficients then are

$$F=\tfrac{63}{2},\ G=-\tfrac{715}{2},\ H=-\tfrac{1005}{4},\ I=-198\,;$$

or the formula is

$$
\begin{aligned}
\beta' = {} & 2n(n-2)(11n-24)\\
& -(110n-272)b + 44q\\
& -(\tfrac{477}{4}n - 315)c + \tfrac{63}{2}r\\
& +\tfrac{715}{2}\beta + \tfrac{1005}{4}\gamma + 198t\\
& -hC - gB - xi - \lambda j - \mu\chi - \nu\theta - f\omega\\
& -h'C' - g'B' - x'i' - \lambda'j' - \mu'\chi' - \nu'\theta' - f'\omega'\,;
\end{aligned}
$$

but I have not as yet any means of determining the coefficients f, f' of the terms in ω, ω'.

From the several cases of a cubic surface we obtain as in the memoir; but applying to the same surfaces the reciprocal equation for β, instead of the results of the memoir, we find

$$\begin{aligned} h' &= -\ \ 4, \\ g'+16\nu &= -198, \\ g'+\ 2\mu &= \ \ 45, \\ g+g' &= \ \ 18, \\ \lambda &= \ \ \ 5 \end{aligned}$$

(so that now $\lambda+\lambda'=-2$, as is also given by the cubic scroll). And combining the two sets of results, we have

$$\begin{aligned} h &= 24, \\ \lambda &= 5, \\ \mu &= \tfrac{27}{2}+\tfrac{1}{2}g, \\ \nu &= -\tfrac{27}{2}+\tfrac{1}{16}g, \\ h' &= -\ 4, \\ g' &= 18-g, \\ \lambda' &= -\ 7, \\ \mu' &= 6-\tfrac{1}{2}g, \\ \nu' &= \tfrac{9}{4}-\tfrac{1}{16}g; \end{aligned}$$

but the coefficients g, x, x', f, f' are still undetermined. To make the result agree with that of the Addition, I assume $x=-86$, $x'=-1$, $g=+28$; whence we have

$$\begin{aligned} \beta' = {} & 2n(n-2)(11n-24) \\ & -(110n-272)b+44q \\ & -(\tfrac{477}{4}n-315)c+\tfrac{63}{2}r \\ & +\tfrac{715}{2}\beta+\tfrac{1905}{4}\gamma+198t \\ & -24C-28B+86i-5j-\tfrac{55}{2}\chi+\tfrac{47}{4}\theta-f\omega \\ & +\ 4C'+10B'+i'+7j'+8\chi'-\tfrac{1}{2}\theta'-f'\omega'; \end{aligned}$$

and if we substitute herein the foregoing value of $44q+\tfrac{63}{2}r$, we obtain

$$\begin{aligned} \beta' = {} & 2n(n-2)(11n-24) \\ & +(-66n+184)b \\ & +(-93n+252)c \\ & +153\beta+93\gamma+66t \\ & -24C-28B-i-27j-38\chi+\tfrac{55}{2}\theta-f\omega \\ & +\ 4C'+10B'+i'+\ 7j'+\ 8\chi'-\tfrac{1}{2}\theta-f'\omega', \end{aligned}$$

which, except as to the terms in ω, ω', the coefficients of which are not determined, agrees with the value given in the Addition.

Dr. ZEUTHEN considers that in general $i'=i$; I presume this is so, but have not verified it.

VI. *Corrections to the Computed Lengths of Waves of Light published in the Philosophical Transactions of the year* 1868. *By* George Biddell Airy, *C.B., Astronomer Royal.*

Received October 2,—Read November 16, 1871.

In a paper communicated to the Royal Society in the year 1867, and printed in the Philosophical Transactions for 1868, I attempted the computation of the Lengths of Waves of Light for all the lines which Kirchhoff had observed in the Solar Spectrum, by adopting an algebraical formula of the fifth order, and substituting in it for every spectral line the value of Kirchhoff's measure for that line, the numerical bases of the formula being derived from Fraunhofer's and Ditscheiner's measures of the wave-lengths for six principal lines. Subsequently I obtained the means of comparing many of my computed results with measures of wave-lengths by Ångström and Ditscheiner, and I found that the discordances were far larger than I had anticipated. I remarked, however, "By means of the comparison ..... there is no difficulty in computing for any other line the correction that ought to be applied to the wave-length in the principal Tables, in order to exhibit the true wave-lengths on Ditscheiner's scale, without appreciable error."

Want of leisure long prevented me from entering upon the examination necessary for preparing, in a form easy for applications, the correction which my numbers required. Lately, however, I have taken it up; and I have constructed a Table of corrections to the numbers of my Table generally, and I have applied them, both to the general Table of wave-lengths and to the values of wave-lengths for the spectral lines of the atmosphere and several metals (the accurate exhibition of which was, in fact, the first object of my computations). I now offer these corrections and corrected numbers for the acceptance of the Royal Society.

The work of comparison and correction was conducted by a graphical process. For this, I refer to the diagram (Plate XII.), premising the following explanations:—The abscissa-measures are the computed numbers for Wave-lengths in the Philosophical Transactions, 1868. The Ordinate-measures are the corrections required to make these computed numbers agree with observed wave-lengths. The crosses represent the corrections required by Ångström; and the dots represent the corrections required by Ditscheiner.

My first step was, adopting my computed numbers as a line of abscissæ, to mark the values of the discordances ("Ångström—computed numbers" and "Ditscheiner—computed numbers") as ordinates. The points thus determined for the two experimenters were placed on the same sheet of paper, but were distinctively marked. The result of

comparison of them was the following:—From G (wave-length about 0·00043000 millim.) to F (49000), although the required corrections are very large, there is no sensible doubt on their value; and the measures of ÅNGSTRÖM and DITSCHEINER, where they are comparable, agree closely. As far as 49400, their accord is good; from that point to about 51600, DITSCHEINER only has given measures. From 51600 to 54000 their measures begin to diverge, and from that point to 56000 they are irreconcilable. Single observations of each at 59000 (D) agree fairly, and they support this inference from DITSCHEINER's measures, that, whatever be the principle adopted in drawing the final curve, there must be a cusp at D. I conceive, therefore, that KIRCHHOFF made some important change in the adjustments of his apparatus at that point. From 61000 to 62000 the two systems of measure cannot be reconciled. Near 65800 (at C) the disagreement, though smaller, is too large, and near 68900 (at B) it is much larger. After this, the only measure is one by ÅNGSTRÖM, for A.

From this statement it will appear that the adoption of a correction-curve is by no means a straightforward process. In the following steps I have been guided in great measure by the wish to make as few sinuosities as possible. From G to a point beyond E (about 54000) there is no general difficulty, and I have given nearly equal values to the two series of points. From 54000 to the cusp at D, and again from the cusp at D to C, I have abandoned ÅNGSTRÖM entirely, the points of DITSCHEINER giving very good curves. But I cannot very well introduce DITSCHEINER's one remaining measure (that at B), and I have continued my curve through ÅNGSTRÖM's two last points, for B and A.

I need not explain to any person who has had much familiarity with operations of this kind, how great has been the advantage of possessing, as basis of comparison, a series of numbers computed on a continuous formula, even though that formula be inaccurate.

Having thus adopted my curve, I measured its ordinates for every 500 in the final figures of the subdivisions of millimetres represented by 0·00000001 millim. In order to extend the Table so as to give the results for every 100 in the final figures, it was necessary, after giving due attention to the progress of the differences preceding and following that difference which is to be divided into five parts, to decide on values of correction which would produce an harmonious flow in the second differences at the reduced intervals. No great difficulty, however, was found in this process. The Table thus formed of corrections to the wave-lengths printed in the Philosophical Transactions, 1868, is the following.

Corrections to the Computed Wave-Lengths in the Table, Philosophical Transactions, 1868, pages 37 to 50.

Computed wave-length, m.m. 0·000.	Correction.	Computed wave-length, m.m. 0·000.	Correction.	Computed wave-length, m.m. 0·000.	Correction.	Computed wave-length, m.m. 0·000.	Correction.	Computed wave-length, m.m. 0·000.	Correction.	Computed wave-length, m.m. 0·000.	Correction.	Computed wave-length, m.m. 0·000.	Correction.
42500	+335	476	−518	527	7	578	+ 97	629	+70	68000	− 66	731	−262
426	+281	477	−476	528	− 10	579	+ 93	63000	+67	681	− 70	732	−266
427	+227	478	−432	529	− 11	58000	+ 87	631	+65	682	− 73	733	−270
428	+173	479	−385	53000	− 12	581	+ 81	632	+62	683	− 77	734	−275
429	+119	48000	−337	531	− 11	582	+ 74	633	+59	684	− 80	73500	−279
43000	+ 65	481	−291	532	10	583	+ 67	634	+57	68500	− 84	736	−283
431	+ 11	482	−211	533	7	584	+ 59	63500	+55	686	− 88	737	−287
432	13	483	−198	534	− 2	58500	+ 50	636	+53	687	− 91	738	−292
433	− 97	484	−151	53500	+ 5	586	+ 42	637	+51	688	− 95	739	−296
434	−152	48500	−105	536	+ 12	587	+ 33	638	+49	689	− 99	74000	−300
43500	−207	486	− 62	537	+ 20	588	+ 23	639	+47	69000	−103	741	−304
436	−261	487	− 20	538	+ 29	589	+ 12	64000	+46	691	−107	742	−309
437	−315	488	+ 21	539	+ 37	59000	0	641	+44	692	−111	743	−313
438	−368	489	+ 61	54000	+ 44	591	+ 7	642	+43	693	−115	744	−318
439	−420	49000	+ 91	541	+ 51	592	+ 14	643	+41	694	−119	74500	−323
44000	−470	491	+120	542	+ 58	593	+ 21	644	+39	69500	−123	746	−328
441	−520	492	+142	543	+ 65	594	+ 28	64500	+37	696	−126	747	−333
442	−570	493	+162	544	+ 72	59500	+ 35	646	+35	697	−130	748	−337
443	−618	494	+180	54500	+ 78	596	+ 43	647	+32	698	−134	749	−342
444	−664	49500	+192	546	+ 84	597	+ 50	648	+30	699	−138	75000	−347
44500	−702	496	+204	547	+ 89	598	+ 58	649	+28	70000	−142	751	−352
446	−740	497	+208	548	+ 94	599	+ 65	65000	+26	701	−146	752	−357
447	−775	498	+211	549	+ 98	60000	+ 72	651	+23	702	149	753	−362
448	−807	499	+214	55000	+102	601	+ 80	652	+21	703	−153	754	−367
449	−834	50000	+213	551	+106	602	+ 88	653	+18	704	−156	75500	−372
45000	−858	501	+210	552	+109	603	+ 96	654	+15	70500	−160	756	−378
451	−882	502	+205	553	+111	604	+103	65500	+12	706	−164	757	−383
452	−902	503	+199	554	+113	60500	+108	656	+ 9	707	−167	758	−389
453	−918	504	+192	55500	+114	606	+113	657	+ 6	708	−171	759	−394
454	930	50500	+184	556	+116	607	+117	658	+ 3	709	−175	76000	−400
45500	−940	506	+178	557	+118	608	+120	659	0	71000	−179	761	−406
456	−948	507	+172	558	+119	609	+122	66000	− 3	711	−183	762	−412
457	−953	508	+166	559	+120	61000	+123	661	− 6	712	−187	763	−418
458	−956	509	+160	56000	+121	611	+122	662	9	713	−190	764	−424
459	−958	51000	+153	561	+121	612	+120	663	−12	714	−194	76500	−430
46000	−955	511	+145	562	+122	613	+118	664	−15	71500	−198	766	−436
461	−950	512	+137	563	+122	614	+115	66500	−18	716	−202	767	−442
462	−942	513	+128	564	+121	61500	+112	666	−21	717	206	768	−448
463	927	514	+119	56500	+121	616	+109	667	−24	718	−210	769	−454
464	−910	51500	+110	566	+120	617	+105	668	−27	719	−214	77000	−460
46500	−890	516	+100	567	+119	618	+102	669	−30	72000	−218	771	−466
466	−866	517	+ 89	568	+118	619	+ 98	67000	−33	721	−222	772	−472
467	−840	518	+ 79	569	+117	62000	+ 95	671	−36	722	−226	773	−478
468	−814	519	+ 68	57000	+115	621	+ 92	672	−39	723	−230	774	−484
469	−784	52000	+ 57	571	+114	622	+ 90	673	−42	724	−234	77500	−490
47000	−749	521	+ 46	572	+113	623	+ 87	674	−45	72500	−238	776	−496
471	−715	522	+ 35	573	+112	624	+ 85	67500	−49	726	−242		
472	−678	523	+ 24	574	+110	62500	+ 82	676	−52	727	−246		
473	−639	524	+ 13	57500	+107	626	+ 79	677	−56	728	−250		
474	−599	52500	+ 5	576	+104	627	+ 76	678	−59	729	−254		
47500	−559	526	− 2	577	+101	628	+ 73	679	−63	73000	−258		

Conversion of Kirchhoff's Spectral Measures into Wave-lengths, in terms of the Millimetre.

Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.		
381·7	77194	1 *c*	
384·1	77079	2 *c*	
385·9	76990	2 *d*	
387·5	76912	3 *d*	
388·9	76844	4 *d*	
390·4	76774	4 *e*	
392·1	76690	5 *e*	
393·6	76620	6 *e*	
395·0	76552	6 *e*	
396·2	76493	5 *e*	
397·4	76437	4 *e*	
398·4	76388	4 *d*	
399·2	76351	4 *d*	
399·8	76321	4 *d*	
400·4	76298	3 *d*	
401·9	76230	4 *c*	
		3	
402·4	76209	4	
402·8	76188	5	
403·2	76169	6	
A 405·0	76086	5	
405·6	76062	4	
406·2	76034		
		3	
406·8	76010	5 *e*	
408·5	75916	1 *d*	
423·7	75261	2 *b*	
426·6	75106	2 *b*	
433·8	74793	2 *c*	
437·0	74656	2 *b*	
442·8	74411	2 *d*	
444·6	74332	2 *c*	
445·8	74283	2 *b*	
446·1	74271	2 *b*	
447·0	74234	2 *a*	
448·4	74173	1 *b*	
452·6	73995	2 *c*	
453·0	73979	1 *b*	
454·4	73921	1 *b*	
460·0	73681	1 *c*	
461·0	73647	1 *b*	
462·2	73589	2 *b*	
463·3	73544	2 *a*	
466·0	73432	1 *b*	
466·5	73411	2 *c*	
467·0	73390	1 *b*	
468·1	73343	2 *e*	
470·0	73261	2 *b*	
470·5	73240	3 *c*	
470·9	73225	2 *b*	
472·4	73161	2 *e*	
472·7	73149	3 *c*	
473·8	73105	4 *d*	
		1	
474·7	73069	3 *b*	
from 475·7	73027	2	
476·4	72997	1 *b*	
		2	
477·0	72972	5 *b*	
		2	
477·8	72940	4 *b*	
479·1	72889	2 *c*	
		1	
480·1	72850	6 *c*	
480·4	72838	4 *d*	
481·2	72807	4 *c*	
482·1	72772	2 *d*	
483·3	72722	4 *d*	
484·1	72693	2 *d*	
485·1	72652	3 *d*	
486·2	72609	6 *e*	
486·8	72585	2 *c*	
from 488·2	72529	1	
488·8	72506	5 *a*	
489·6	72472	6 *c*	
491·2	72408	3 *e*	
491·5	72397	5 *b*	
491·9	72378	4 *c*	
493·1	72334	2 *c*	
494·1	72292	3 *b*	
495·4	72241	1 *e*	
495·7	72229	2 *b*	
497·2	72166	1 *b*	
497·5	72155	2 *a*	
498·4	72119	4 *c*	
499·0	72093	5 *b*	
499·9	72058	5 *d*	
500·8	72025	3 *d*	
501·8	71987	2 *c*	
502·0	71981	5 *b*	
502·6	71958	5 *c*	
503·8	71909	6 *d*	
504·3	71890	5 *b*	
505·1	71861	6 *c*	
506·2	71817	2 *b*	
506·4	71810	5 *b*	
506·6	71801	2 *b*	
507·4	71772	5 *c*	
508·2	71738	3 *b*	
509·1	71703	3 *b*	
509·9	71672	2 *b*	
510·9	71634	1 *a*	
512·9	71558	2 *b*	
513·6	71533	3 *b*	
517·1	71404	2 *b*	
519·3	71314	2 *b*	
521·6	71231	1 *b*	
529·4	70945	1 *b*	
530·4	70907	1 *c*	
532·8	70818	1 *b*	
536·9	70667	2 *b*	
537·3	70654	1 *b*	

TABLE (continued).

Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.		
540·6	70538	3 *b*	
541·1	70519	2 *c*	
542·0	70484	1 *a*	
543·6	70427	4 *b*	
544·6	70392	3 *d*	
547·0	70305	4 *c*	
547·9	70273	2 *b*	
549·6	70211	3 *c*	
551·2	70157	3 *c*	
552·5	70112	3 *c*	
(553·8	70063	1 *c*	
554·0	70058	3 *b*	
554·6	70035	2 *b*	
557·0	69954	1 *a*	
557·7	69928	2 *b*	
558·1	69914	1 *b*	
559·7	69857	1 *c*	
561·5	69798	1 *b*	
562·5	69764	3 *b*	
563·0	69746	2 *c*	
564·1	69709	4 *c*	
565·0	69675	2 *c*	
566·0	69640	2 *c*	
566·9	69609	2 *b*	
567·4	69591	3 *b*	
(568·6	69551	2 *b*	
		1	
569·2	69532	2 *b*	
		1	
570·0	69502	3 *c*	
570·6	69482	2 *b*	
572·2	69427	3 *b*	
572·9	69402	1 *b*	
573·6	69379	3 *c*	
574·4	69351	1 *b*	
575·1	69328	2 *d*	
576·6	69279	2 *d*	
578·1	69229	3 *d*	
579·6	69175	3 *d*	
581·1	69125	3 *c*	
582·5	69081	3 *e*	
583·8	69029	4 *e*	
585·0	68999	4 *f*	
586·2	68959	4 *e*	
587·0	68931	3 *e*	
587·9	68902	2 *b*	
589·0	68868	3 *b*	
589·4	68854	3 *b*	
589·9	68838	3 *b*	
590·3	68825	3 *b*	
590·7	68812	3 *b*	
591·1	68797	3 *b*	
591·5	68784	4 *b*	
591·9	68771	4 *b*	
592·3	68759	3 *b*	
B (592·7	68756	6 *c*	
593·1	68733	4 *g*	
595·0	68670	1 *a*	
596·6	68616	1 *a*	

Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.		
597·4	68591	1 *b*	
601·2	68470	1 *a*	
601·8	68450	1 *b*	
602·8	68417	1 *a*	
606·0	68316	1 *b*	
608·3	68239	1 *a*	
612·4	68113	1 *b*	
613·4	68079	1 *a*	
623·4	67771	1 *b*	
626·1	67687	1 *b*	
631·4	67525	1 *b*	
638·4	67313	1 *b*	
639·8	67268	1 *b*	
641·0	67232	2 *b*	Ca
645·3	67103	1 *b*	
648·1	67018	1 *b*	
654·3	66836	2 *b*	
659·3	66689	2 *a*	
665·7	66505	2 *a*	
669·5	66395	2 *b*	
678·6	66142	1 *b*	
681·4	66063	1 *a*	
682·8	66024	1 *b*	
683·1	66016	2 *a*	
685·3	65954	1 *b*	
689·8	65831	2 *b*	
690·9	65801	1 *a*	
692·1	65769	2 *a*	
C { from (693·4	65734	1	Air
694·1	65715	6 *c*	
to 694·8	65696	1	
698·1	65607	2 *a*	
700·0	65556	2 *a*	
701·1	65526	2 *b*	
702·1	65499	2 *a*	
702·6	65485	1 *b*	
705·5	65410	2 *a*	
705·9	65399	2 *a*	
707·5	65356	1 *b*	
708·6	65329	2 *b*	
710·5	65277	2 *c*	
711·4	65253	3 *c*	
712·0	65238	2 *b*	
713·2	65206	1 *b*	
714·4	65173	1 *c*	
717·8	65083	2 *b*	Ca
from (718·7	65060	2	Ba
719·6	65037	3 *a*	
720·1	65026	2 *e*	Ca
721·1	64999	2 *b*	Fe
723·7	64931	2 *c*	
724·2	64918	1 *b*	
725·1	64896	1 *b*	Air
726·7	64855	3 *c*	
727·8	64826	1 *c*	
728·0	64821	2 *a*	
729·0	64795	2 *b*	Ca
731·7	64727	5 *b*	Ca
734·0	64668	1 *d*	

TABLE (continued).

Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.			Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.		
[illegible]	[illegible]	3 [illegible]	[illegible]	[illegible]	[illegible]	1	
[illegible]	[illegible]	5 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
743·7	64423	2 *b*		839·2	62227	2 *b*	
744·3	64408	4 *b*		845·7	62096	2 *b*	
748·1	64313	4 *b*		849·7	62013	3 *c*	Fe
748·7	64299	3 *b*		851·2	61980	1 *a*	
750·1	64263	1 *a*		851·8	61967	1 *a*	
751·0	64242	1 *b*		855·0	61904	2 *a*	
752·3	64208	4 *b*		856·8	61867	2 *a*	
753·8	64173	3 *b*	Sr	857·5	61853	2 *a*	
756·9	64094	5 *b*	Fe	858·3	61838	2 *a*	
759·3	64035	3 *b*		859·7	61809	3 *a*	
764·2	63916	1 *a*		860·2	61798	3 *d*	Ca
771·8	63734	1 *a*	Zn	861·6	61769	2 *a*	
773·4	63696	2 *b*		862·2	61756	1 *a*	
774·8	63664	2 *b*		863·2	61739	2 *c*	
778·3	63579	1 *b*	(Ru, Ir)	863·9	61725	5 *b*	Ca
779·5	63553	1 *b*		864·4	61715	1 *d*	
781·9	63494	3 *b*		866·2	61678	2 *b*	
783·1	63468	4 *b*		867·1	61660	2 *b*	
783·8	63454	3 *b*		867·6	61650	1 *a*	
786·8	63382	1 *a*		869·2	61619	2 *b*	
788·9	63333	3 *b*		870·9	61585	1 *b*	
791·0	63284	1 *d*		871·4	61574	2 *b*	
791·4	63276	3 *b*		872·5	61553	1 *b*	
792·9	63243	2 *d*		874·0	61526	1 *b*	
794·5	63208	1 *d*		874·3	61520	4 *b*	Ba
798·1	63125	3 *a*		876·5	61474	4 *a*	
798·5	63115	4 *a*	Fe	877·0	61465	4 *c*	Fe
799·8	63086	2 *b*		879·8	61410	1 *b*	
800·3	63072	2 *b*		880·9	61389	1 *a*	
801·2	63055	1 *a*		881·6	61374	2 *a*	
801·5	63048	1 *a*		882·6	61356	1 *a*	
802·7	63020	1 *b*		883·2	61343	1 *b*	
803·5	63004	2 *a*		884·9	61311	4 *b*	Ca, Co
805·8	62951	1 *b*		887·7	61256	2 *a*	Ni
807·4	62917	2 *b*		890·2	61208	1 *b*	Ba
808·2	62898	2 *c*		891·7	61178	2 *a*	Ni
808·7	62888	1 *c*		894·9	61113	2 *c*	Ca, Li
809·5	62869	3 *b*	Au	896·1	61091	1 *a*	
809·9	62858	2 *d*		896·7	61080	1 *b*	
812·7	62798	1 *a*		898·9	61034	1 *a*	
813·1	62791	2 *a*		899·1	61031	1 *a*	
815·0	62749	4 *b*		900·2	61010	1 *a*	
816·8	62709	2 *b*		901·4	60985	1 *a*	
818·0	62685	3 *c*		901·6	60981	1 *a*	
819·0	62662	4 *b*		902·4	60965	1 *a*	
820·1	62638	4 *b*		903·1	60950	1 *a*	
820·9	62623	4 *b*		903·6	60941	1 *a*	
823·5	62565	1 *a*		904·6	60923	1 *a*	
824·0	62554	4 *b*		906·1	60892	2 *c*	
824·9	62535	1 *d*		912·1	60774	3 *b*	Fe
826·4	62504	2 *a*		*916·3	60690	2 *b*	
827·6	62478	1 *a*		923·0	60558	2 *b*	
828·0	62467	2 *a*		929·5	60428	2 *b*	
830·2	62419	3 *b*		931·3	60393	4 *b*	Fe
831·0	62404	4 *c*	Fe	932·5	60371	4 *b*	
831·7	62388	1 *b*		933·3	60355	4 *c*	
836·5	62286	2 *b*		935·1	60319	4 *b*	

:es, from 916·3 to 1006·8, are included in a subsequent Table of Atmo-

TABLE (continued).

Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.		
936·7	60287	4 *b*	
937·4	60274	1 *b*	
940·1	60217	3 *b*	
940·4	60210	2 *b*	
943·4	60153	3 *b*	
946·6	60091	3 *b*	
947·0	60084	1 *a*	
949·4	60037	1 *b*	
949·8	60029	1 *b*	
951·7	59992	1 *c*	
952·9	59969	3 *b*	
954·3	59944	3 *b*	
954·8	59935	3 *b*	
958·8	59859	3 *b*	
959·6	59845	3 *b*	
961·9	59799	1 *a*	
963·7	59764	1 *c*	
964·4	59753	1 *c*	
968·7	59673	2 *a*	
969·0	59668	2 *a*	
969·6	59657	3 *a*	
970·5	59640	1 *b*	
971·5	59619	2 *c*	
972·1	59608	1 *b*	
973·1	59590	3 *a*	
973·5	59582	3 *a*	
974·3	59569	2 *a*	
975·0	59556	2 *a*	
976·8	59521	3 *a*	
977·4	59510	2 *a*	
977·7	59504	2 *a*	
979·1	59479	1 *b*	
980·8	59450	1 *a*	
981·2	59444	3 *b*	
982·0	59429	1 *a*	
982·3	59424	2 *a*	
983·0	59411	3 *c*	
984·5	59384	1 *c*	
986·3	59352	1 *a*	
986·7	59346	2 *c*	
987·4	59332	1 *b*	
988·9	59304	2 *a*	
989·2	59298	2 *a*	
989·6	59291	2 *a*	
990·8	59270	2 *a*	
991·2	59263	1 *a*	
991·9	59250	3 *b*	Fe
992·4	59241	1 *a*	
993·9	59213	1 *b*	
994·3	59205	1 *b*	
995·0	59193	1 *a*	
997·2	59155	2 *b*	
998·1	59139	1 *a*	
998·9	59125	1 *a*	
999·2	59120	1 *a*	
1000·0	59106	1 *a*	
1000·4	59100	1 *a*	
1001·4	59083	1 *a*	
D *b* 1002·8	59054	6 *b*	Na

Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.		
1005·0	59018	2 *b*	Ni
D *a* 1006·8	58989	6 *b*	Na
1011·2	58926	3 *a*	
1023·0	58756	1 *a*	
1025·5	58720	3 *a*	
1027·7	58690	2 *a*	
1029·3	58666	3 *c*	Ca, Ni
1031·8	58626	2 *a*	Ba
1032·8	58612	1 *a*	
1035·3	58576	1 *a*	
1058·0	58257	2 *b*	
1063·0	58185	2 *b*	
1065·0	58155	2 *b*	
1066·0	58143	1 *a*	
1067·0	58130	2 *b*	
1070·5	58078	2 *b*	
1073·5	58036	1 *a*	
1074·2	58027	1 *a*	
1075·5	58008	3 *a*	
1077·5	57982	1 *a*	
from 1078·9	57960	} 1	
to 1079·7	57949		
1080·3	57940	1 *a*	
1080·9	57932	1 *a*	
1081·8	57920	2 *b*	Cu
1083·0	57902	2 *a*	Ba
1087·5	57838	2 *a*	
1089·6	57810	2 *a*	
1096·1	57720	3 *c*	Fe
1096·8	57711	1 *a*	
1097·8	57696	1 *a*	
1100·4	57659	1 *a*	
1102·1	57633	3 *b*	
1102·9	57623	3 *a*	
1103·3	57618	2 *b*	
1104·1	57605	2 *b*	
1107·1	57563	2 *c*	
1111·4	57507	1 *a*	
1119·0	57401	2 *a*	
1122·6	57357	2 *a*	
1128·3	57275	2 *b*	
1130·9	57240	2 *b*	
1133·1	57212	3 *c*	
1133·9	57201	3 *c*	
1135·1	57182	4 *d*	
1135·9	57171	2 *c*	
1137·0	57158	2 *b*	
1137·8	57149	3 *b*	
1141·3	57100	2 *c*	
1143·6	57072	2 *c*	
1146·2	67038	1 *b*	
1147·2	57025	1 *b*	
1148·6	57007	1 *b*	
1149·4	56996	1 *b*	
1151·1	56969	4 *b*	
1152·5	56952	2 *b*	
1154·2	56929	2 *b*	
(1155·7	56908	3 *b*	
(1155·9	56906	2 *c*	

TABLE (continued).

Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.			Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.		
1158·3	56874	2 *a*		1264·4	55552	1 *a*	
1160·9	56843	2 *a*		1264·9	55547	2 *a*	
1165·2	56785	1 *a*		1267·3	55519	3 *a*	
1165·7	56779	1 *a*		1268·0	55511	3 *a*	
1167·0	56764	1 *d*		1271·9	55464	1 *a*	
1168·3	56747	1 *a*		1272·4	55459	1 *a*	
1169·4	56732	1 *a*		1274·2	55438	3 *b*	Ba
1170·6	56716	2 *c*		1274·7	55431	3 *a*	Sr
1174·2	56670	5 *d*		1276·2	55414	2 *a*	
1175·0	56661	2 *a*		1276·7	55408	1 *a*	
1176·6	56639	3 *c*		1280·0	55369	6 *d*	
1177·0	56634	2 *a*		1281·3	55356	3 *c*	
1177·3	56630	1 *a*		1282·6	55341	2 *c*	
1177·6	56626	1 *a*		1285·3	55308	2 *c*	
1178·6	56615	1 *a*		1287·5	55284	1 *c*	Ba
1179·0	56610	1 *a*		1289·7	55256	2 *c*	
1179·4	56604	1 *a*		1291·9	55232	3 *c*	
1179·8	56599	1 *a*		1293·8	55211	3 *c*	
1180·2	56593	1 *a*		1294·5	55203	3 *c*	
1183·4	56553	2 *a*		1295·6	55188	1 *a*	
1184·8	56534	3 *a*		1296·3	55180	2 *c*	
1186·8	56507	2 *a*		1297·5	55165	1 *a*	
1187·1	56504	2 *a*		1298·9	55148	5 *c*	
1189·3	56477	3 *b*		1299·7	55139	2 *c*	
1190·1	56467	2 *b*		1302·0	55114	2 *c*	
1193·1	56429	3 *a*		1303·5	55096	5 *c*	
1199·6	56345	2 *d*		1306·7	55058	5 *c*	
1200·6	56332	4 *b*	Fe	1315·0	54962	4 *c*	
1201·0	56326	2 *a*		1315·7	54953	2 *b*	
1203·5	56297	2 *c*		1319·0	54916	3 *c*	Co
1204·2	56288	2 *c*		1320·6	54899	4 *c*	Sr
1204·9	56280	2 *d*		1321·1	54891	3 *b*	
1206·1	56264	1 *c*		1323·3	54866	2 *b*	
1207·3	56250	5 *g*	Fe	1324·0	54857	2 *b*	
1217·8	56118	5 *d*	Fe, Ca	1324·8	54849	4 *d*	Ni
1219·2	56102	3 *c*	Ca	1325·3	54843	2 *d*	
1220·1	56091	2 *c*		1327·7	54816	4 *b*	
1221·6	56072	5 *d*	Ca	1328·7	54805	2 *b*	
1224·7	56033	5 *d*	Ca	1330·4	54785	3 *b*	
1225·3	56024	1 *b*		1333·3	54752	1 *a*	
1226·6	56008	2 *d*		1334·0	54744	4 *b*	
1228·3	55988	2 *d*	Ca	1336·3	54720	1 *b*	
1229·6	55972	4 *c*	Ca	1337·0	54711	4 *d*	Fe
1230·5	55961	2 *c*		1337·8	54703	1 *b*	
1231·3	55952	5 *d*	Fe	1338·5	54693	1 *b*	
1232·8	55933	2 *b*		1343·5	54637	6 *c*	Fe
1235·0	55906	3 *d*	Ca	1351·1	54554	5 *d*	Fe
1237·8	55871	2 *c*		1352·7	54531	5 *b*	Fe
1239·9	55846	4 *a*	Fe	1356·5	54490	1 *a*	
1242·6	55814	6 *c*	Fe	1360·9	54443	1 *a*	
1245·6	55777	4 *d*	Fe	1361·6	54435	1 *a*	
1247·4	55756	3 *b*		1362·9	54420	5 *b*	Fe
1248·6	55742	3 *d*		1364·3	54405	1 *a*	
1250·4	55721	3 *c*		1364·7	54400	1 *a*	
1251·1	55713	2 *b*		1367·0	54375	6 *d*	Fe
1253·3	55686	2 *b*		1371·4	54324	1 *b*	Ba
1255·2	55663	2 *b*		1372·1	54317	1 *b*	
1257·5	55635	3 *c*		1372·6	54311	5 *b*	Fe
1258·5	55624	2 *b*		1374·8	54286	1 *c*	

TABLE (continued).

Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.		
1375·8	54272	2 *a*	
1377·4	54256	1 *a*	
1379·0	54238	1 *a*	
1380·5	54223	4 *c*	Fe
1384·7	54173	4 *c*	Fe
1385·7	54164	5 *b*	Cr
1386·3	54158	2 *b*	
1387·4	54147	2 *b*	
1389·4	54126	6 *c*	Fe
1390·9	54112	5 *d*	Fe
1394·2	54074	4 *c*	
1395·3	54062	1 *c*	
1396·4	54050	2 *c*	
1397·5	54039	5 *c*	Fe
1400·2	54005	3 *b*	
1401·6	53989	4 *c*	Fe
1403·1	53975	3 *c*	
1404·1	53966	1 *b*	
1405·2	53954	3 *b*	
1410·5	53896	4 *c*	Fe
1412·5	53874	2 *b*	
1414·0	53859	2 *b*	
1415·8	53838	2 *b*	
1419·4	53797	2 *b*	
1421·5	53773	6 *c*	Fe
1423·0	53759	5 *b*	Fe
1423·5	53753	2 *b*	
1425·4	53734	5 *b*	Fe
1427·5	53709	3 *b*	
1428·2	53704	5 *b*	Fe
1430·1	53683	5 *b*	
1431·2	53671	1 *b*	
1438·9	53590	4 *c*	Co
1440·2	53578	1 *b*	Co
1443·1	53549	2 *b*	
1443·5	53544	2 *b*	Ca
1444·4	53535	4 *b*	
1446·7	53514	4 *c*	
1448·7	53492	2 *a*	Co
1449·4	53483	1 *a*	Co
1450·8	53465	5 *c*	Fe
1451·8	53455	5 *b*	Fe
1453·7	53437	1 *a*	
1454·7	53425	3 *b*	
1456·6	53407	1 *a*	
1458·6	53385	3 *c*	
1461·5	53355	2 *c*	
1462·2	53347	2 *c*	
1462·8	53341	5 *c*	Fe
1463·3	53338	5 *c*	Fe
1464·8	53320	1 *a*	
1465·3	53317	1 *a*	
1466·8	53302	5 *c*	Fe
1468·8	53282	2 *b*	
1469·6	53272	1 *b*	
1473·9	53234	5 *b*	Fe
1475·3	53220	1 *a*	
1476·8	53205	1 *a*	
1477·5	53198	1 *a*	

Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.		
1483·0	53148	4 *b*	
1487·7	53102	5 *b*	Fe
1489·2	53087	2 *c*	
1489·9	53082	1 *a*	
(1491·2	53070	1 *c*	
1491·6	53067	3 *c*	
1492·4	53059	4 *b*	
1493·1	53053	4 *b*	
1494·5	53038	1 *a*	
1495·9	53024	1 *a*	
1497·3	53012	1 *a*	Cu
1501·3	52976	2 *b*	
1504·8	52944	1 *a*	
1505·3	52938	1 *a*	
1505·7	52936	2 *a*	
1506·3	52930	5 *c*	Fe
1508·6	52908	5 *b*	Fe
1510·3	52893	2 *c*	Co
1515·5	52844	4 *d*	
1516·5	52837	4 *c*	
1519·0	52813	4 *d*	
E {1522·7	52782	6 *c*	Fe, Ca
1523·7	52772	6 *c*	Fe
1525·0	52761	1 *b*	Co
1527·7	52738	5 *c*	Fe, Co
1528·7	52731	5 *c*	Ca
1530·2	52717	4 *c*	Ca
1531·2	52707	4 *c*	
1532·5	52698	4 *b*	Ca
1533·1	52694	4 *b*	Ca
(1541·4	52619	1 *g*	
1541·9	52615	3 *b*	
1543·7	52599	2 *a*	
1545·5	52583	2 *a*	
1547·2	52570	3 *a*	
1547·7	52566	2 *a*	
1551·0	52542	2 *a*	
1551·6	52535	2 *a*	
1555·6	52500	2 *a*	
1557·3	52488	3 *a*	
1561·0	52459	1 *a*	
1564·2	52434	1 *a*	
1566·5	52414	2 *b*	Co
1567·5	52406	2 *b*	
1569·6	52391	5 *c*	Fe
1573·5	52360	5 *a*	
1575·4	52346	1 *b*	
(1577·2	52332	5 *c*	Fe
1577·6	52329	3 *c*	
1579·4	52317	2 *a*	
1580·1	52312	2 *a*	
1588·3	52247	1 *g*	Cu
1589·1	52242	3 *b*	
1590·7	52231	3 *b*	
1592·3	52217	3 *b*	
1598·9	52166	2 *b*	
(1601·4	52148	6 *b*	Cr
1601·7	52145	3 *d*	
1604·4	52126	5 *b*	Cr

TABLE (continued).

Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.		
1606·4	52110	5 *b*	Cr
1609·2	52086	5 *b*	
1611·3	52072	1 *c*	
1613·9	52053	3 *b*	
1615·6	52040	2 *b*	
1616·6	52036	1 *b*	
1617·4	52029	2 *b*	
1618·2	52022	3 *b*	
1618·9	52018	4 *b*	
1621·5	51996	1 *b*	
1622·3	51990	5 *c*	Fe
1623·4	51981	5 *b*	Fe
1627·2	51953	5 *b*	Ca
1628·2	51946	1 *b*	
1631·5	51922	1 *b*	
b (1633·5	51907	4 *g*	
1634·1	51902	6 *g*	Mg
1634·7)	51898	4 *g*	
1638·7	51870	1 *b*	
1642·1	51844	1 *b*	
1643·0	51838	1 *b*	Ni
1647·3	51805	5 *a*	
(1648·4	51797	4 *c*	
b_1 1648·8	51793	6 *f*	Mg
1649·2)	51791	4 *e*	
1650·3	51783	6 *b*	Fe
b_2 {(1653·7	51757	6 *b*	Fe, Ni
1654·0)	51758	4 *c*	
(1655·6	51742	6 *e*	Fe, Mg
1655·9)}	51739	4 *d*	
1657·1	51731	5 *b*	
(1658·3	51724	2 *b*	
to 1659·4)	51716	1	
1662·8	51693	5 *b*	Fe
1667·4	51658	3 *a*	
1670·3	51638	1 *a*	
1671·5	51630	3 *b*	
1672·2	51625	4 *a*	Ni
1673·7	51615	4 *a*	
1674·7	51607	3 *c*	Cu
(1676·2	51595	2 *d*	
1676·5)	51593	4 *b*	
1677·9	51582	4 *c*	
1681·6	51554	4 *c*	
1684·0	51538	4 *a*	Ni
1684·4	51535	1 *b*	
1685·9	51523	2 *a*	
1686·3	51520	2 *a*	
1689·5	51498	5 *c*	
1690·0	51494	5 *b*	Ni
1691·0	51487	5 *b*	
1693·8	51467	6 *e*	Fe
1696·5	51447	3 *c*	
1697·0	51443	3 *c*	Ni
1701·8	51411	5 *c*	Fe
(1704·6	51391	2 *c*	
1704·9)	51389	3 *b*	
(1707·6	51370	2 *c*	
1707·9)	51368	3 *b*	

Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.		
1710·7	51349	5 *a*	
1712·2	51338	3 *b*	
1713·4	51331	5 *b*	
1715·2	51317	4 *b*	
1717·9	51297	4 *b*	
1719·4	51286	1 *c*	
1726·9	51233	1 *a*	
1727·3	51230	3 *b*	Ni
1733·6	51185	5 *b*	
1734·6	51178	3 *b*	
1737·7	51155	5 *d*	
1741·0	51131	4 *b*	Cu
1742·7	51119	1 *a*	
1743·1	51117	1 *a*	
1744·6	51106	2 *a*	
1748·9	51076	3 *c*	Ni
1749·6	51071	2 *d*	Ni
1750·4	51066	5 *c*	
1752·0	51056	2 *b*	
1752·8	51050	4 *c*	
1762·0	50986	3 *c*	
1771·5	50917	3 *c*	
1772·5	50912	3 *c*	
1774·0	50899	2 *b*	
1775·8	50887	3 *b*	Ni
1776·5	50883	3 *c*	Ni
1777·5	50876	3 *c*	
1778·5	50868	3 *c*	
1782·7	50839	3 *b*	
1784·4	50826	1 *b*	
1785·0	50822	4 *b*	
1787·7	50802	2 *c*	
1788·7	50795	3 *b*	
1793·8	50762	4 *b*	
1795·4	50751	1 *a*	
1796·0	50747	3 *a*	
1797·8	50736	1 *a*	
1799·0	50727	4 *c*	
1799·6	50723	3 *b*	
1806·4	50677	2 *b*	
1818·7	50595	5 *b*	
1821·4	50577	5 *b*	
1822·6	50570	3 *a*	
1823·2	50565	2 *a*	
1823·6	50562	2 *a*	
1828·6	50527	1 *b*	
1830·1	50518	3 *b*	
1832·8	50501	2 *a*	Ca
1833·4	50497	6 *c*	
1834·3	50491	6 *c*	
1835·9	50482	3 *b*	
1836·7	50476	3 *c*	
1837·5	50472	3 *c*	
1841·0	50446	4 *b*	
1841·6	50443	4 *b*	
1842·2	50439	4 *b*	Ni
1848·9	50395	2 *c*	
1851·0	50379	1 *c*	
1853·2	50364	3 *b*	

TABLE (continued).

Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.	·	
1854·0	50359	2 *b*	
1854·9	50354	4 *c*	
1856·9	50341	1 *c*	
1857·9	50336	2 *b*	
1860·4	50318	2 *b*	
1861·3	50312	3 *c*	
1862·3	50305	2 *b*	
1864·9	50290	3 *b*	
1867·1	50274	5 *d*	Fe
1868·4	50265	5 *b*	Ni
1869·5	50258	1 *c*	
1870·6	50250	3 *a*	
1872·4	50237	5 *b*	
1873·4	50230	6 *b*	
1874·2	50226	2 *a*	
1874·8	50222	2 *a*	
1875·8	50215	2 *c*	
1876·5	50210	6 *b*	
1884·3	50159	6 *b*	
1885·8	50147	6 *b*	
1886·4	50143	6 *b*	
1889·5	50122	1 *g*	
1891·0	50112	3 *b*	
1892·5	50104	5 *b*	
1893·8	50092	1 *b*	
1894·8	50084	3 *b*	
1896·2	50074	4 *b*	
1897·9	50063	1 *c*	
1900·0	50047	1 *c*	
1904·5	50017	4 *b*	
1905·1	50013	2 *c*	
1908·5	49989	5 *d*	
1911·9	49965	3 *c*	
1916·2	49935	1 *d*	
1917·5	49927	4 *b*	
1917·9	49924	4 *b*	
1919·8	49912	4 *b*	
1920·2	49909	4 *b*	Ni
1921·1	49902	4 *b*	
1922·0	49897	4 *b*	
1922·4	49893	4 *b*	
1923·5	49885	4 *b*	
1925·8	49868	4 *b*	Ni
1928·0	49853	4 *b*	
1931·2	49830	1 *c*	
1932·5	49823	1 *c*	
1936·2	49796	3 *c*	
1939·5	49775	2 *c*	
1940·6	49766	2 *c*	
1941·5	49760	3 *b*	
1943·5	49746	2 *c*	
1944·5	49740	3 *b*	
1947·6	49717	4 *c*	
1949·4	49703	1 *c*	
1953·6	49672	2 *b*	
c 1960·8	49621	6 *b*	
		4	Fe
1961·2	49615	6 *b*	
1964·3	49593	2 *c*	
1966·2	49578	2 *b*	
1966·7	49573	2 *b*	
1970·1	49548	3 *b*	
1974·7	49514	4 *b*	
1975·7	49506	2 *d*	
1979·2	49481	3 *c*	
1982·8	49454	5 *a*	
1983·3	49449	5 *a*	
1983·8	49445	5 *a*	
1984·5	49440	4 *b*	
1985·8	49430	4 *b*	
1986·9	49421	2 *a*	
1987·5	49418	3 *a*	Ni
1989·5	49402	6 *c*	Ba
1990·4	49394	5 *b*	
1991·8	49383	1 *b*	
1994·1	49365	5 *b*	
1996·9	49343	2 *a*	
1997·5	49340	2 *a*	
1999·6	49324	2 *c*	
2000·6	49313	5 *a*	
2001·6	49304	5 *c*	Fe
2003·2	49292	3 *b*	
2003·7	49289	1 *a*	
2004·9	49280	2 *d*	
2005·2	49279	6 *d*	Fe
2007·2	49263	6 *c*	Fe
2008·1	49255	1 *b*	Ni
2008·6	49251	1 *b*	
2009·8	49242	2 *b*	
2013·9	49212	2 *a*	
2014·3	49210	2 *a*	
2015·7	49198	1	
2016·9	49189		
2017·7	49181	2 *b*	
		1	
2018·5	49176	2 *b*	
2019·5	49169	2 *a*	
2021·2	49153	1 *g*	
2024·9	49123	1 *a*	
2025·7	49112	4 *a*	Ni
2026·8	49106	4 *b*	
2031·1	49073	2 *c*	Ba
2035·4	49038	1 *b*	
2039·6	49005	1 *b*	
2041·3	48991	6 *c*	Fe
2042·2	48983	6 *b*	Fe
2044·5	48966	5 *b*	
2045·0	48962	5 *b*	
2047·0	48944	3 *d*	
2047·8	48939	3 *b*	
2049·3	48925	3 *a*	
2049·7	48923	3 *a*	
2051·3	48908	3 *c*	
2053·0	48892	4 *b*	
2053·7	48885	4 *c*	
2058·0	48849	6 *c*	FeCa
2060·0	48832	2 *b*	
2060·6	48827	2 *a*	

TABLE (continued).

Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.		
2061·0	48824	1 *a*	
2064·7	48790	2 *c*	Ni
2066·2	48778	5 *c*	Fe
2067·1	48770	5 *c*	Fe
2067·8	48766	3 *b*	
2068·8	48758	3 *b*	
2070·6	48740	1 *b*	
2071·3	48735	1 *b*	Co
2073·5	48719	3 *b*	Ni
2074·6	48709	2 *b*	
2076·5	48693	1 *b*	
2077·3	48686	2 *b*	
F (2079·5	48666	4 *c*	
2080·0	48663	6 *g*	
2080·5	48660	4 *c*	
2082·0	48642	6 *a*	Fe
2084·6	48624	2 *b*	
2086·0	48610	1	
to 2086·9	48603		
2086·9	48603	3 *b*	Ni
2087·6	48598	1 *a*	
2089·7	48583	1 *a*	
2090·9	48573	1 *a*	
2094·0	48546	2 *b*	
2096·8	48523	1 *b*	
2098·8	48505	1 *a*	
2099·8	48499	2 *a*	
2100·4	48494	1 *a*	
2102·6	48475	4 *a*	
2103·3	48469	4 *b*	
2104·0	48463	4 *a*	
2105·1	48456	4 *b*	
2107·0	48439	1 *a*	
2107·4	48435	2 *a*	
2109·1	48424	2 *b*	
2111·1	48405	3 *b*	
2112·7	48391	3 *b*	Ni
2115·0	48372	3 *a*	Ni
2115·4	48367	3 *a*	
2119·8	48331	1 *b*	
2121·2	48316	4 *b*	
2121·9	48311	5 *c*	
2124·3	48290	1 *b*	
2125·1	48284	2 *b*	
2127·7	48260	3 *b*	
2132·3	48219	2 *a*	Co
2132·7	48213	1 *a*	
2133·8	48203	2 *a*	
2134·3	48200	1 *a*	
2136·0	48186	5 *a*	Zn
(2138·0	48169	2 *g*	
2138·4	48165	4 *a*	
2139·5	48154	4 *a*	
2140·4	48147	4 *a*	
2141·9	48135	2 *a*	
2142·4	48131	5 *a*	
2144·6	48112	4 *a*	
2146·9	48092	3 *a*	
2147·4	48089	4 *a*	
2148·5	48079	4 *a*	
2148·9	48076	3 *a*	
2150·1	48069	3 *a*	
2150·5	48068	3 *a*	
2157·0	48014	3 *a*	Co, Au
2157·4	48011	5 *a*	
2159·0	47998	1 *c*	
2160·6	47984	5 *a*	
2160·9	47981	4 *a*	
2161·7	47975	4 *a*	
2162·6	47966	3 *a*	
2163·7	47957	4 *a*	
2164·0	47952	4 *a*	Ni
2167·5	47924	6 *b*	
2171·5	47889	3 *b*	Ca
2172·2	47884	2 *a*	
2175·7	47854	2 *b*	
2176·4	47849	1 *b*	
2179·9	47819	5 *b*	
2181·2	47808	3 *c*	
2184·9	47780	5 *b*	
2186·5	47769	3 *b*	
2187·1	47764	5 *a*	
2187·9	47757	5 *a*	
2188·5	47752	5 *a*	
2190·1	47739	5 *b*	
(2191·9	47725	3 *c*	
2192·3	47721	5 *b*	
2193·3	47713	5 *a*	
2195·7	47688	2 *b*	
2197·1	47678	2 *b*	
2197·7	47673	2 *b*	
2198·8	47663	4 *a*	
2199·2	47660	3 *a*	Ni
2201·1	47645	2 *b*	
2201·9	47638	5 *c*	
2203·3	47626	2 *a*	
2203·8	47623	1 *a*	
2205·1	47611	1 *b*	
2206·4	47601	1 *a*	Ca
2206·7	47598	1 *a*	
2209·1	47578	4 *c*	
2211·7	47556	4 *b*	
2213·4	47542	4 *b*	
2215·1	47529	1 *b*	
2216·7	47515	3 *b*	
2217·5	47507	3 *b*	
2218·3	47501	3 *a*	
2219·8	47489	3 *b*	
2221·3	47476	1 *a*	
2221·7	47473	1 *a*	
2222·3	47469	5 *c*	
2223·5	47459	3 *c*	
2225·4	47443	2 *b*	
2226·2	47434	4 *b*	
2227·6	47428	2 *a*	
2228·6	47415	2 *a*	
2229·1	47410	4 *a*	
2230·7	47397	4 *a*	

TABLE (continued).

Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.		
2231·2	47392	2 *a*	
2232·3	47385	4 *a*	
(2233·7	47372	5 *c*	
(2234·0	47369	2 *c*	
2237·4	47345	1 *b*	
2238·7	47336	1 *b*	
2240·0	47324	3 *b*	Zn
2241·4	47310	2 *b*	
2245·1	47281	3 *b*	
2246·2	47272	1 *b*	
2248·2	47256	3 *c*	
(2249·7	47246	6 *a*	Ni
(2250·0	47241	3 *d*	
2255·4	47198	4 *b*	
2256·2	47193	2 *b*	
2257·1	47185	4 *d*	
2257·6	47181	2 *b*	
2258·5	47175	2 *c*	
2259·4	47171	4 *c*	
2261·4	47156	1 *b*	
2262·1	47152	2 *a*	
2263·4	47142	2 *a*	
2264·3	47136	6 *d*	
2266·2	47121	2 *a*	
2266·6	47118	2 *a*	
2268·0	47105	3 *a*	
2269·1	47098	3 *a*	
2269·9	47092	3 *a*	
2270·2	47089	3 *a*	
2274·2	47064	1 *d*	
2278·4	47026	4 *c*	
2279·8	47018	2 *a*	
2280·7	47009	2 *a*	
2282·0	46998	1 *a*	
2282·3	46996	1 *b*	
2283·6	46984	2 *a*	
2284·9	46975	2 *b*	
2286·1	46966	2 *b*	
2288·1	46949	2 *a*	
from (2289·1	46942	1	
(2289·9	46935	2 *b*	
2290·4	46931	1 *b*	
2291·8	46921	2 *g*	Zn
(2293·1	46910	2 *a*	
		1	
(2293·6	46905	3 *b*	
2294·5	46898	2 *b*	Cd
2301·7	46840	4 *c*	
2302·9	46829	3 *b*	
2305·3	46807	3 *d*	
2306·8	46797	4 *c*	
2307·8	46788	1 *b*	
2308·2	46786	5 *b*	
to (2309·0	46780	5 *c*	
(2310·4	46770	1	
2310·9	46766	2 *c*	
2312·5	46752	3 *b*	
2313·7	46742	3 *b*	
2314·3	46737	3 *b*	

Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.		
2316·0	46723	2 *b*	
2316·6	46718	1 *b*	
2322·0	46676	2 *b*	
2323·0	46669	2 *b*	
2325·3	46649	6 *d*	
2328·3	46626	5 *b*	
2329·5	46618	5 *b*	Cu
(2332·8	46592	2 *b*	
(2333·0	46589	5 *d*	
2334·1	46581	2 *d*	Ni
2335·0	46574	5 *b*	
2336·2	46565	2 *d*	
2336·8	46561	5 *b*	
2339·9	46540	4 *b*	
2342·5	46519	1 *d*	
from (2343·7	46508	1	
(2345·1	46496	2 *d*	
2346·7	46483	4 *b*	
2347·3	46478	4 *b*	
2349·4	46464	1 *b*	
2349·9	46460	2 *b*	
2351·4	46446	1 *c*	
2352·2	46441	2 *b*	
2354·1	46426	6 *c*	
2357·4	46401	5 *a*	
2358·4	46390	5 *b*	
2361·0	46371	1 *d*	
2362·2	46363	1 *c*	
2362·6	46362	4 *b*	
2364·0	46350	4 *b*	
2365·9	46336	2 *b*	
2366·8	46330	1 *b*	
2367·7	46323	2 *b*	
2369·7	46309	2 *b*	
(2371·4	46295	2 *b*	
(2371·6	46294	4 *b*	
2372·4	46287	4 *b*	
2374·2	46272	3 *b*	
2375·0	46268	2 *b*	
2375·6	46264	4 *b*	
2376·1	46259	1 *b*	
2379·0	46236	6 *c*	
2381·6	46217	6 *c*	
2386·1	46185	3 *b*	
2386·6	46181	2 *a*	
2388·7	46163	2 *c*	
2389·7	46155	2 *c*	
2390·7	46149	3 *a*	
2391·2	46143	1 *b*	
2393·1	46131	5 *b*	
2394·4	46121	4 *a*	
(2395·8	46111	1 *f*	
(2396·1	46110	3 *b*	
(2396·7	46106	2 *a*	
		1	
(2397·4	46099	2 *a*	
2399·6	46084	3 *a*	
2399·9	46082	3 *a*	
2402·2	46061	3 *b*	

TABLE (continued).

Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.		
2403·2	46052	3 *b*	
2404·9	46041	2 *b*	
2406·2	46032	2 *b*	
2406·6	46029	6 *c*	
2407·2	46022	1 *b*	
2408·2	46016	4 *b*	
2409·0	46009	1 *b*	
2410·2	46000	4 *b*	
2412·8	45985	3 *b*	
2414·7	45969	2 *b*	
2416·0	45961	3 *d*	
2416·3	45957	5 *b*	
2418·0	45946	3 *b*	
2419·3	45937	5 *b*	
2420·6	45927	2 *b*	
2422·3	45915	6 *d*	Co
2423·8	45904	3 *c*	
2424·4	45899	4 *b*	
2426·5	45885	4 *b*	
2428·4	45871	1 *a*	
2429·5	45864	3 *b*	
2431·9	45846	2 *b*	
2432·4	45842	1 *b*	
2435·3	45820	2 *b*	
2435·5	45819	5 *c*	
2435·7	45816	2 *b*	
2436·5	45810	5 *a*	
2438·5	45796	1 *a*	
2439·4	45789	2 *b*	
2440·0	45784	1 *a*	
2441·8	45770	2 *a*	
2442·4	45767	1 *a*	
2443·9	45755	5 *a*	
2444·2	45753	5 *a*	
2445·3	45745	1 *c*	
2446·6	45735	5 *b*	
2452·1	45698	2 *c*	
2454·1	45678	4 *b*	
2457·5	45656	4 *b*	
2457·9	45652	4 *b*	
2458·6	45647	3 *a*	
2459·5	45640	2 *b*	
2460·4	45632	1 *c*	
2461·2	45626	6 *b*	Ba
2463·4	45609	4 *b*	
2466·0	45588	3 *a*	
2467·3	45579	3 *c*	
2467·6	45576	5 *c*	
2467·9	45574	3 *c*	
2468·7	45568	3 *a*	
2470·1	45558	4 *a*	
2471·2	45550	2 *b*	
2471·4	45548	4 *a*	
2472·9	45537	4 *a*	
2473·8	45530	2 *c*	
2474·6	45524	4 *b*	
2475·5	45519	1 *c*	
2477·4	45503	2 *a*	
2477·8	45500	2 *a*	
2478·7	45495	2 *a*	
2479·7	45486	2 *a*	
2480·1	45484	2 *a*	
2481·1	45475	1 *a*	
2482·1	45471	1 *a*	
2482·4	45467	1 *c*	
2486·6	45437	5 *b*	
2487·0	45433	5 *b*	
2488·2	45426	4 *b*	
2489·4	45418	5 *d*	
2490·5	45411	5 *a*	
2490·8	45408	3 *d*	
2493·0	45394	3 *a*	
2493·6	45390	5 *a*	Co
2493·9	45388	3 *f*	
2495·8	45375	5 *b*	
2497·2	45364	6 *d*	
2499·0	45352	3 *b*	
2499·8	45346	3 *b*	
2500·3	45342	4 *c*	
2502·2	45329	4 *c*	Ba
2502·4	45327	1 *b*	
2505·6	45304	4 *d*	
2509·4	45279	2 *d*	
2512·1	45258	1 *c*	
2512·5	45256	2 *a*	
2513·2	45252	2 *b*	
2513·5	45249	1 *b*	
2517·0	45226	3 *b*	
2518·2	45216	2 *c*	
2518·4	45214	3 *a*	
2520·9	45199	3 *a*	
2522·3	45189	1 *a*	
2525·0	45172	2 *a*	
2525·4	45168	1 *b*	
2527·0	45156	4 *a*	
2532·0	45124	2 *b*	
2535·5	45100	2 *b*	
2535·9	45096	2 *b*	
2536·6	45092	1 *b*	
2537·1	45089	5 *c*	
2538·0	45082	1 *b*	
2538·3	45080	2 *a*	
2540·5	45067	2 *g*	Pt
2543·5	45047	4 *c*	
2544·5	45040	2 *d*	
2545·4	45034	1 *c*	
2547·2	45020	6 *c*	
2547·7	45016	2 *b*	
2548·4	45012	1 *c*	
2549·7	45003	1 *b*	
2550·1	45000	1 *b*	
2551·2	44991	1 *b*	
2551·4	44989	3 *a*	
2552·4	44983	3 *a*	
2552·6	44981	1 *b*	
2553·6	44975	3 *a*	
2554·0	44972	3 *a*	

TABLE (continued).

Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.		
2554·9	44965	3 *a*	
2555·1	44964	2 *c*	
2556·3	44955	2 *c*	
2559·9	44932	3 *b*	
2562·1	44917	4 *b*	
2564·0	44905	3 *b*	
2565·0	44898	6 *c*	
2565·9	44891	2 *b*	
2566·3	44888	3 *d*	
2567·8	44879	3 *b*	
2568·4	44875	2 *b*	
2574·4	44834	5 *c*	
2579·3	44801	3 *d*	
2581·0	44790	1 *a*	
2581·5	44786	1 *a*	
2582·0	44783	2 *a*	
2582·4	44779	2 *a*	
2582·8	44776	1 *a*	
2584·0	44767	3 *c*	
2585·4	44759	5 *b*	
2587·9	44741	3 *a*	
2588·5	44737	5 *b*	
2589·7	44729	1 *b*	
2591·3	44718	4 *a*	
2591·7	44715	2 *c*	
2593·0	44705	1 *c*	
2594·9	44693	2 *b*	
		1	
2595·4	44690	4 *a*	
2595·9	44686	4 *a*	
		1	
2596·4	44682	2 *c*	
2597·7	44673	3 *b*	
2598·5	44668	1 *b*	
2599·4	44662	3 *c*	
2599·7	44661	5 *b*	
2600·6	44654	2 *a*	
2601·0	44651	2 *c*	
2602·1	44643	4 *b*	
2602·9	44636	1 *a*	
2603·6	44631	2 *b*	
2604·0	44628	1 *a*	
2604·8	44623	4 *b*	
2605·8	44616	3 *b*	Ca
		2	
2606·6	44610	5 *c*	
2607·1	44607	3 *c*	
2608·2	44599	1 *c*	
2608·6	44597	1 *b*	
2608·9	44595	1 *a*	
2610·2	44587	1 *a*	
2612·3	44573	3 *b*	
2613·6	44564	2 *c*	
2614·1	44561	3 *c*	
2616·5	44547	2 *b*	
2619·1	44530	5 *b*	
2619·9	44525	3 *a*	
2620·3	44522	3 *a*	
2622·3	44509	1 *b*	

Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.		
2624·1	44495	1 *b*	
2625·2	44487	5 *a*	
·2625·9	44482	4 *a*	
2626·3	44479	2 *a*	
2627·0	44475	5 *b*	
2627·9	44468	2 *a*	
2628·9	44462	1 *c*	
2629·7	44458	1 *b*	
2630·5	44452	1 *a*	
2633·6	44431	2 *c*	
2634·4	44427	1 *d*	
2635·5	44420	3 *b*	
2636·4	44415	2 *c*	
2637·4	44408	4 *b*	
2638·5	44400	4 *c*	Ca
2638·8	44398	5 *a*	
2639·6	44393	1 *c*	
2640·6	44386	2 *c*	
2641·6	44379	3 *c*	
2642·5	44374	2 *a*	
2643·2	44371	1 *a*	
2643·5	44369	1 *a*	
2645·6	44355	4 *b*	
2646·2	44351	2 *g*	(La, Di)
2650·5	44326	5 *b*	
2650·7	44324	3 *c*	
2652·9	44309	1 *d*	Ca
2653·2	44307	5 *b*	
from 2656·7	44286	1	
2657·9	44280	3 *b*	
2658·6	44275	1 *b*	
2664·9	44236	3 *a*	
2665·9	44229	3 *b*	
2666·7	44224	1 *b*	
2667·6	44216	3 *a*	
2668·0	44215	1 *b*	
2669·4	44205	3 *b*	
*f** 2670·0	44201	6 *c*	Fe
2673·8	44176	1 *a*	
2674·5	44171	2 *a*	
2675·6	44163	2 *c*	
2676·5	44156	2 *a*	
2677·2	44151	1 *a*	
2678·4	44143	1 *a*	
2679·0	44139	2 *a*	
2680·0	44133	5 *b*	
2680·2	44131	3 *b*	
2681·2	44125	5 *a*	
2683·1	44112	4 *b*	
2686·0	44093	3 *c*	
2686·4	44091	6 *f*	Fe
2686·8	44089	3 *c*	
2688·4	44077	2 *c*	
2690·8	44061	5 *b*	
2691·1	44059	3 *e*	
2692·3	44052	3 *c*	
2693·5	44045	4 *c*	
from 2695·2	44033	1	
to 2696·8	44023		

* The identification of *f* appears doubtful.—G. B.

TABLE (continued).

Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.		
2698·2	44015	1 *f*	
from 2699·8	44005	1	
2700·7	44000	2 *a*	
2702·1	43992	3 *b*	
2702·3	43991	4 *a*	
2702·5	43989	3 *b*	
2703·5	43984	3 *a*	
from 2703·8	43981	1	
to 2704·9	43975		
2707·4	43960	1 *f*	
2707·7	43958	3 *a*	
2708·9	43951	4 *b*	
2709·6	43945	2 *b*	
2710·6	43940	3 *a*	
2710·9	43938	1 *g*	
2711·9	43932	1 *a*	
2712·8	43926	2 *a*	
2713·3	43923	3 *a*	
2714·3	43917	2 *a*	
2715·2	43913	2 *b*	
2716·1	43907	1 *d*	
2718·5	43893	3 *g*	
2719·0	43890	4 *c*	
		1	
2720·2	43883	2	
2720·8	43879	6	Fe
2721·6	43874		
2722·8	43867	3	
2725·5	43852	2 *d*	
2725·8	43849	3 *a*	
2726·8	43843	2 *a*	
2728·0	43835	4 *b*	
2728·4	43833	1 *b*	
2729·8	43825	2 *c*	
2730·7	43820	1 *b*	
2731·6	43814	3 *c*	
2732·4	43809	1 *c*	
2733·7	43802	5 *b*	
2734·1	43799	3 *b*	
		1	
2735·7	43790	3 *b*	
2736·5	43785	3 *b*	
2736·9	43783	3 *b*	
2737·4	43779	1 *a*	
2737·8	43777	2 *a*	
2739·2	43769	2 *c*	
2739·9	43765	1 *b*	
2741·3	43757	3 *d*	
2741·7	43754	3 *b*	
2743·8	43741	1 *f*	
2744·1	43740	4 *c*	
2744·3	43739	1 *d*	
2746·8	43724	1	
2747·2	43722		
2747·6	43720	3 *a*	
2748·0	43718	4 *c*	
2749·8	43709	3 *c*	
2750·6	43705	3 *a*	
2754·5	43682	2 *c*	

Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.	
2755·4	43677	1 *b*
2755·8	43676	2 *b*
2756·5	43671	1 *c*
2757·2	43667	1 *c*
2759·4	43655	1 *a*
2760·1	43652	2 *a*
2760·6	43649	2 *d*
2762·0	43641	4 *c*
2763·8	43631	3 *f*
2767·2	43613	1 *d*
2768·2	43607	2 *a*
2768·5	43606	1 *a*
2770·0	43598	2 *b*
2770·8	43594	2 *b*
2774·0	43577	5 *c*
2775·4	43571	4 *c*
2775·7	43569	6 *c*
2776·0	43567	4 *c*
2777·3	43559	3 *a*
		2
2777·8	43557	
		1
2778·5	43554	
2781·2	43540	2 *b*
2782·2	43534	1 *b*
2782·9	43531	3 *b*
2783·9	43525	1 *b*
2784·8	43521	1 *c*
2785·1	43519	2 *c*
2788·8	43499	1 *b*
2789·1	43498	3 *c*
2790·5	43491	1 *c*
2791·1	43487	3 *b*
2793·0	43477	1
2794·0	43473	2
2795·7	43465	6
2796·7	43460	
		2
2797·6	43455	3 *b*
		2
2798·0	43453	3 *b*
		1
2798·9	43448	2 *c*
		1
2799·5	43445	2 *c*
		1
2800·1	43443	3 *b*
		1
2800·7	43440	3 *b*
		1
2801·4	43435	4 *d*
2804·5	43419	1 *b*
2805·4	43414	1 *b*
2806·9	43405	1 *c*
2807·2	43403	2 *a*
2808·6	43396	1 *b*
2808·8	43395	2 *a*
2809·0	43394	1 *b*
2810·8	43384	2 *b*

TABLE (continued).

Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.		
2811·7	43379	2 *a*	
2812·0	43377	2 *a*	
2812·5	43375	2 *a*	
2812·8	43373	1 *c*	
2814·1	43366	1 *b*	
2817·7	43346	3 *c*	
2819·2	43338	3 *b*	
2819·6	43336	2 *b*	
2820·6	43331	2	
2821·0	43329	3	
2821·6	43325		
2822·3	43322	6	Fe
		3	
2823·4	43317	4 *c*	
2824·2	43313	3 *a*	
		2	
2825·0	43309	4 *c*	
		3	
2825·9	43304	4 *b*	
		3	
2826·5	43300	4 *c*	
2828·9	43288	3 *b*	
2830·7	43278	3 *g*	
2834·2	43260	5 *c*	Ca
2837·7	43241	1 *g*	
2841·4	43221	5 *b*	
2841·7	43219	4 *c*	
2843·0	43211	3 *d*	
2843·3	43209	4 *a*	
2844·0	43205	3 *b*	
2845·3	43195	4 *f*	
		2	
2846·1	43191	3 *c*	
		2	
2846·9	43186	4 *c*	
		1	
2847·7	43181	4 *a*	
		2	
2848·0	43179	4 *a*	
		2	
2848·4	43177	3 *b*	
		2	
2848·9	43174	3 *b*	
		2	
2849·3	43172	3 *b*	
		2	
2849·8*	43168	3 *b*	
		2	
2850·2	43167	3 *b*	
		2	
2850·7	43163	3 *b*	
		2	
2851·1	43161	3 *b*	
		2	

Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.		
2851·6	43158	3 *b*	
		2	
2852·0	43155	4 *a*	
		2	
2852·3	43154	4 *a*	
		1	
2853·1	43148	3	
2853·6	43145	4	
2854·1	43142	6	Fe
G 2854·7	43138	4	Ca
2855·2	43135	3	
2855·7	43132		
2856·9	43124	4 *d*	
from 2857·9	43119	3	Sr
2858·5	43116	4 *a*	
		2	
2858·9	43113		
		3	
2859·4	43110		
		1	
2860·2	43105		
2860·9	43101	2	
		1	
2861·7	43097	4 *b*	
2861·9	43095	3 *b*	
		1	
2863·1	43088	3 *b*	
2863·6	43085		
		4	
2864·2	43081	5 *b*	
		2	
2864·7	43079	4 *b*	Ca
		2	
2865·3	43075	4 *c*	
		1	
2866·3	43069	5 *b*	
		3	
2867·1	43065		
		2	
2868·1	43058	4 *c*	
		3	
2869·7	43048	5 *c*	Ca
		4	
2871·2	43039		
2872·2	43033	4 *d*	
		1	
2873·4	43025	2 *b*	
		1	
2873·9	43022	2 *b*	
		1	
2874·3	43019	3 *b*	
		1	
2874·7	43017	2 *b*	
		1	
2875·2	43014	4 *c*	

The following Tables are to be substituted for those in pages 51, 52, 53, of the Memoir in the Philosophical Transactions, 1868.

Conversion of KIRCHHOFF's Spectral Measures into Wave-Lengths in terms of the Millimetre, for the lines produced by Metals and Air.

(The lines marked with an asterisk appear to coincide with dark lines in the Solar Spectrum)—Note by KIRCHHOFF.

Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.	
Ce		
1190·1	56467	1
1249·9	55727	1
1256·7	55645	1
1329·1	54799	2
1332·4	54764	2
1336·2	54721	1
1385·0	54170	2
1401·7	53988	2
*1438·9	53591	3
1460·9	53359	1
1517·9	52824	3
from 1571·0	52381	1
to 1572·4	52369	
1573·0	52364	2
1623·1	51984	1
from 1629·2	51937	2
to 1630·4	51931	
1683·1	51544	1
1725·5	51243	1
*1777·5	50877	2
from 1782·4	50843	1
to 1784·5	50823	
1938·8	49780	2
2052·3	48899	1
2221·5	47473	1
Di		
1225·0	56028	2
1230·0	55966	1
from 1364·5	54402	1
to 1365·2	54394	
1431·9	53664	1
1471·1	53261	1
from 1518·6	52818	1
*to 1519·4	52810	
1536·0	52669	1
1541·4	52619	1
1548·9	52556	2
*1567·5	52406	1
1709·2	51359	2
La		
from 1411·6	53885	2
*to 1412·8	53871	
1416·8	53827	2
1451·0	53464	1
1606·8	52107	2
1627·9	51949	2
1634·8	51898	2
2136·8	48178	1
(La, Di)		
1025·0	58726	1
1064·5	58162	1
1066·1	58141	1
1071·1	58067	1
1075·6	58007	1
1077·0	57988	1
1092·1	57776	2
*1302·0	55114	1
*1303·4	55097	2
1317·6	54931	1
1345·4	54617	1
from 1486·8	53110	2
*to 1489·2	53087	
*1622·3	51990	1
*1623·3	51982	1
1716·6	51307	2
1728·8	51219	2
from 1894·5	50086	2
*to 1895·2	50082	
1903·0	50027	1
1940·2	49769	1
from 1988·6	49408	1
to 1989·5	49402	
2003·8	49289	1
2004·7	49282	2
2031·0	49043	2
2081·0	48655	2
2121·4	48314	1
2208·2	47587	2
2214·5	47533	2
2217·8	47506	2
Pd		
1114·7	57460	1
*1146·2	57038	2
1164·9	56789	2
1185·6	56524	1
1264·6	55551	2
1269·0	55489	2

Table (continued).

Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.		Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.	
1279·1	55380	1	2123·6	48295	2
from 1400·0	54007	2	2162·0	47973	2
*to 1400·7	54000				
1430·1	53683	1	Pt		
1447·0	53509	1	1325·7	54838	1
1477·0	53202	1	from 1488·2	53097	3
1495·2	53030	3	to 1489·0	53089	
1540·0	52632	1	1576·8	52326	1
from 1566·5	52414	2	from 1806·1	50678	2
to 1567·1	52409		*to 1806·9	50673	
1601·4	52149	1	2057·0	48857	1
from 1660·0	51712	3			
to 1660·7	51707		(Ru, Ir)		
1732·9	51190	2	1348·3	54582	2
1801·9	50708	1	*1489·9	53082	1
2062·0	48814	2			

Atmospheric Lines.

Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.		Kirchhoff's measure.	Corrected wave-length, m.m. 0·000.	
711·4	65252		977·7	59504	
948·0	60062		982·0	59429	
949·4	60037		982·3	59424	
949·8	60029		988·9	59304	
951·7	59992		989·2	59299	
954·2	59945		989·6	59291	
958·8	59859		993·1	59230	
959·6	59845		993·4	59220	
961·9	59800		998·1	59139	
963·7	59764		999·2	59120	
964·4	59753		1000·0	59106	
965·7	59730		1001·4	59084	
968·7	59669		1005·8	59004	
969·0	59668		1008·3	58968	
969·6	59657		1009·2	58955	
970·5	59640		1010·5	58936	
972·1	59608		1013·9	58888	
974·3	59568		1015·1	58871	
975·0	59556		1016·4	58852	
975·7	59540		1017·7	58834	
976·1	59534		1018·2	58826	
977·4	59510				

Measures of Wave-Lengths, in Millimetres, for the Spectral Lines produced by Air and different Metals: collected from the Tables in the Phil. Trans. 1868, and corrected by the general Table of Corrections above.

Air.	Ba	Ca	Cr	Fe	La	Na	Pd
m.m. 0·000.	m.m. 0·000.	m.m. 0·000.	m.m. 0·000.	m.m. 0·000.	m.m. 0·000.	m.m. 0·000.	m.m. 0·000.
65734	65060	43135	54164	54222	53884	59057	52409
65716	61520	43079	52148	54173	53871	58989	52149
65696	61208	43049	52126	54125	53827	**Ni**	51712
65252	58626	**Cd**	52110	54111	53461	61257	51707
64896	57902	64494	**Cu**	54039	52107	61178	51190
60084	55438	46898	57920	53989	51948	59018	50707
60063	55283	**Ce**	53012	53896	51902	58666	48814
60037	54324	56467	52248	53773	48179	54849	48296
60029	49402	55727	51607	53759	**(La, Di)**	51838	47974
59992	49073	55644	51131	53734	58727	51757	**Pt**
59944	45626	54799	46618	53704	58162	51625	54838
59860	45329	54764	**Di**	53465	58142	51538	53097
59845	45327	54721	56028	53456	58067	51494	53089
59800	**Ca**	54170	55966	53341	58007	51443	52336
59764	67232	53988	54402	53338	57988	51230	50678
59753	65083	53591	54394	53302	57776	51076	50673
59730	65026	53349	53664	53234	55114	51071	48857
59669	64795	52824	53261	53102	55097	50887	45067
59668	64727	52381	52818	52930	54931	50883	**(Ru, Ir)**
59657	64595	52369	52810	52908	54617	50439	63579
59640	64494	52364	52669	52782	53110	50265	54582
59608	61798	51984	52619	52772	53087	49909	53082
59568	61725	51938	52556	52739	51990	49868	**Sr**
59556	61311	51931	52406	52391	51982	49418	64173
59540	61113	51544	51359	52332	51307	49254	55431
59534	58666	51243	**Fe**	51990	51219	49117	54899
59510	56118	50876	64999	51981	50087	48790	43119
59504	56102	50843	64094	51783	50082	48719	43116
59429	56072	50826	63115	51757	50027	48603	43113
59424	56033	49780	62404	51742	49769	48388	**Zn**
59304	55988	48899	62013	51693	49408	48372	63734
59299	55972	47472	61465	51467	49402	47953	48186
59291	55906	**Co**	60774	51411	49288	47661	47323
59230	53544	61311	60393	50274	49282	47246	46921
59213	52782	54916	59250	49617	49074	46580	
59139	52731	53589	57720	49615	48654	**Pd**	
59120	52717	53578	56332	49304	48313	57460	
59106	52698	53492	56250	49279	47586	57038	
59083	52694	53483	56118	49263	47533	56789	
59004	51953	52893	55952	48991	47506	56524	
58967	50501	52761	55846	48982	44351	55551	
58955	48849	52739	55814	48849	**Li**	55499	
58936	44616	52414	55777	48777	61112	55380	
58888	44611	48735	54711	48770	**Mg**	54007	
58871	44607	48218	54637	48645	51902	54000	
58852	44400	48013	54554	44198	51793	53683	
58834	44398	47889	54531	44091	51742	53509	
58826	44309	47600	54420	43878		53202	
Au	44307	45915	54375	43874		53030	
62869	43262	45389	54312	43323		52632	
48013	43139			43142		52414	
				43139			

These values of the wave-lengths are, I trust, worthy of confidence. They may be liable to errors of 20 or perhaps 30 in the last figures, but, I think, to no greater error.

A very elaborate investigation of the values of Wave-lengths of the Spectral Lines of the Elements has been published by Dr. WOLCOTT GIBBS, in the American Journal of Science and Arts, vol. xlvii. The basis upon which Dr. GIBBS proceeds is not the same as mine (for instance, in the relative merit attached to ÅNGSTRÖM and DITSCHEINER); some measures by HUGGINS and VAN DER WILLINGEN are employed, and some new lines introduced; and the fundamental treatment is different. The results, therefore, are not identical with mine. But, as far as I have examined, the differences between Dr. GIBBS's numbers and my own are small; not greater, I think, than can be explained by such errors as I have specified in the last paragraph.

I have not yet succeeded in finding any relation between the values of wave-length for different lines of the same element, which can suggest any mechanical explanation of their origin.

VII. *On the Normal Paraffins.* *By* C. Schorlemmer, *F.R.S.*

Received December 20, 1871,—Read February 1, 1872.

In the year 1858 Berthollet proved that the compound CH_3 Cl, obtained by the action of chlorine upon marsh-gas, was identical with methyl chloride, by converting it into methyl alcohol and other methyl compounds. Since that time the researches of Pelouze and Cahours, as well as my own, have shown that this method is a general one, and that by means of it the corresponding alcohol may be prepared from any paraffin.

On oxidizing some of the alcohols obtained by this method, acids were formed containing the same number of carbon atoms in the molecule as the alcohols themselves contained, from which it would appear that these alcohols were primary alcohols.

Pelouze and Cahours, however, stated that the octyl alcohol which was obtained from octane contained in petroleum was identical with the so-called capryl alcohol prepared from castor-oil, and Chapman afterwards came to the same conclusion. At that time it was believed that capryl alcohol was a primary alcohol. However, by the study of its oxidation products I found this not to be the case, but that this alcohol belongs to the group of secondary alcohols, being methyl-hexyl carbinol*. It was therefore necessary to repeat the experiments of Pelouze and Cahours and Chapman, and to study carefully the oxidation products of the alcohol from petroleum, which none of these chemists had done. The result of my investigation was that this alcohol is a mixture of methyl-hexyl carbinol with a primary octyl alcohol†.

This observation made it highly probable that, by acting with chlorine upon the paraffins, primary and secondary chlorides are formed at the same time; and the more so, as I had formerly found an acetone amongst the oxidation products of the amyl alcohol from petroleum, the origin of which I was then at a loss to explain‡. As I have already stated in a preliminary note, further experiments with hexane fully confirmed the correctness of my supposition.

The reasons why, in my former researches, I overlooked the secondary compounds are the following:—

The mixture from which the chlorides had to be isolated contained, besides large quantities of unattacked hydrocarbon, also higher chlorinated products. The difference between the boiling-points of the two chlorides is about 10°, but by far the greatest portion distils within these limits at a nearly constant temperature; and as by fractional distillation the boiling-point becomes yet more constant, and the quantity of liquid distilling at this temperature increases, I believed I had obtained a pure compound, and considered the smaller quantities of liquids boiling a little above and below the constant

* Proc. Roy. Soc. vol. xvi. p. 376. † Ibid. vol. xviii. p. 25. ‡ Ibid. vol. xvi. p. 372.

point to consist of mixtures of the chloride with the paraffin, or with higher chlorinated products.

To convert the chlorides into the alcohols, they were first heated with potassium acetate; during this operation a large quantity of the secondary chloride splits up into hydrochloric acid and an olefine, from which the acetic ethers formed had again to be separated by fractional distillation. From the highest boiling fraction, which of course consisted chiefly of the primary acetate, the alcohol was then prepared; but the quantity obtained was so small, that the acid formed by oxidizing it could not be isolated, and its existence was only proved by analyzing the silver salt, in the preparation of which the small quantity of the acetone remained in aqueous solution and was thus overlooked.

As soon as I had ascertained that by acting with chlorine upon the paraffins a mixture of primary and secondary chlorides is formed, the problem next to be solved was under what conditions the one or the other is formed.

In order to obtain decisive results, it was first of all required to work with large quantities of a hydrocarbon; and I chose for my first experiments the *hexyl hydride* or *hexane*, C_6H_{14}, from petroleum, a hydrocarbon which can be obtained most easily in a sufficient quantity. The hexane was treated with chlorine under the following conditions:—

(1) Dry chlorine was passed into the well-cooled hydrocarbon in diffused daylight.

(2) It was acted upon in the cold by chlorine in presence of iodine.

(3) Chlorine was passed into the vapour of the boiling hydrocarbon.

(4) Chlorine was passed into the vapour in the presence of iodine.

The result was that in all four cases, as first product, a mixture of primary and secondary hexyl chlorides was formed. Further, it was found that when chlorine acts on the liquid hydrocarbon, or when iodine is present, always large quantities of higher chlorinated products are formed, but that by passing chlorine to the vapour, the formation of these bodies can be almost completely avoided. In investigating the other paraffins, to be described further on, I always used the latter method.

The apparatus employed consisted of a large flask, which, by means of a cork, was connected on one side with the chlorine apparatus by a tube reaching to the lower end of the neck, and on the other side with a reversed LIEBIG's condenser, the upper end of which was further connected with absorption-bottles containing caustic soda solution, and in which the hydrocarbon which was carried away by the current of hydrochloric acid was condensed. On passing a moderately strong current of dry chlorine into the vapour of the gently boiling hydrocarbon, the colour of the chlorine disappears instantaneously, and the chloride formed is seen to flow back in oily streaks on the side of the vessel. The operation was interrupted in the evening, the hydrocarbon not acted upon distilled off, and treated repeatedly in the same way until a sufficient quantity of the chlorides had been formed. The latter were then heated with the required quantity of potassium acetate, and an equal volume of glacial acetic acid in sealed tubes to 190° to

200° for two or three hours, by which they were completely decomposed. On diluting the contents of the tubes with water, a light layer, a mixture of olefines and acetates, separated out, from which, after drying, the acetates were isolated by fractional distillation, and then decomposed by an alcoholic solution of caustic potash. The alcohols thus obtained were repeatedly washed with small quantities of water and dried, first with fused potassium carbonate, and finally with anhydrous baryta.

Whilst neither a mixture of the two chlorides nor of the acetic ethers can be separated even approximately into its constituents, it is, however, easy to obtain from the mixed alcohols two liquids, each having a nearly constant boiling-point. But although apparently a definite separation has thus been effected, the bodies obtained in this manner are far from being pure compounds. This might have been expected *à priori*, as the difference between the boiling-points of the two alcohols is only about 10°. The products of oxidation showed that the lower boiling liquid consisted principally of the secondary alcohol, but still mixed with some of the primary; whilst in the higher boiling liquid, besides a large quantity of primary alcohol, also some secondary was contained.

In order to oxidize the alcohols, I used, as in my former researches, a solution consisting of two parts of potassium dichromate, three parts of sulphuric acid, and ten parts of water, which was added gradually to the alcohols until the brownish colour of the liquid indicated an excess of chromic acid, care being taken at the same time to keep the liquids as cold as possible. After standing for some time, and being repeatedly shaken, the liquid was diluted with water and distilled, when the acetone formed passed over with the first portion. The residue was again distilled with water, and this operation repeated as long as the distillate exhibited an acid reaction. The aqueous distillates were neutralized with sodium carbonate, the acetone which dissolved in them separated by distillation, and the solution of the sodium salts evaporated to dryness. By adding dilute sulphuric acid to the residue, the acid was liberated and dried with phosphorus pentoxide.

*Normal Amyl Hydride or Pentane**, C_5H_{12}.

This hydrocarbon is a mobile colourless liquid, boiling at 37° to 39°, which I first discovered in the light oils from cannel tar†; it is also found in boghead tar, and in large quantities in Pennsylvania petroleum. According to PELOUZE and CAHOURS, the amyl hydride from petroleum boils at 30°‡, whilst WARREN has found that it contains two isomerides, C_5H_{12}, one boiling at 30°·2 and the other at 37°§. My last researches agree with WARREN'S statement. I have formerly stated that the amyl hydride from petroleum boiled at 35°‖; but this body, as well as the derivatives which I prepared from it, are, as I have now found, only mixtures. The petroleum which I used for this research

* HOFMANN calls this hydrocarbon *quintane* and its derivatives *quintyl compounds*. I prefer the names *pentane* and *pentyl*, as corresponding with hexyl and heptyl, which terms are now in general use.

† Journ. Chem. Soc. vol. xv. p. 419.

‡ Ann. Chim. Phys. [4] vol. i. p. 5.

§ Chem. News, vol. xiii. p. 74, from Mem. Amer. Academy.

‖ Proc. Roy. Soc. vol. xv. p. 131.

contained but small quantities of the hydrocarbon boiling at 30°; by long-continued and carefully conducted fractional distillation I succeeded in obtaining about 800 cub. centims. of pure pentane, boiling constantly at 37° to 39°, the boiling-point of which was not altered by further distillations.

The mixture of pentyl chloride obtained by the method described above boiled between 95° and 110°, the principal fraction distilling at 100° to 102°. On decomposing these chlorides with potassium acetate, a mixture of pentene boiling at 39° to 40°, and of the acetic ethers boiling at 135° to 145°, was formed. The latter were converted into the alcohols, which by fractional distillation could be separated into two portions, one boiling at 120° to 122°, and the other at 134° to 137°. The products of oxidation of the alcohols were found to consist of *methyl-propyl ketone*, $\left.\begin{matrix} C\,H_3 \\ C_3\,H_7 \end{matrix}\right\}CO$, and *normal valerianic* or *pentylic acid*.

Methyl-propyl ketone is a colourless liquid boiling at 102° to 105°, having the same boiling-point as the ketone obtained by the distillation of a mixture of calcium acetate and butyrate, and that formed by oxidation of isoamylic alcohol. It combines with the bisulphites of the alkali-metals, and yields by further oxidation acetic and propionic acids. The aqueous distillate containing these acids was neutralized with sodium carbonate, the solution evaporated, and from the residue the acids liberated by successive distillations with insufficient quantities of sulphuric acid in four fractions, from which, by boiling with silver carbonate, the silver salts were prepared, which were analyzed.

Calculated for silver propionate	. . . .	59·67 per cent.
First fraction, small, white needles,	0·335 gave 0·199 Ag=59·6	per cent.
Second fraction was lost.		
Third fraction, indistinct needles,	0·481 gave 0·307 Ag=63·69	per cent.
Fourth fraction, shining flat needles,	0·2095 gave 0·135 Ag=64·5	per cent.
Calculated for silver acetate	. . . .	64·67 per cent.

The acid derived from the primary pentyl alcohol contained small quantities of acetic and propionic acids, which were easily removed by distillation. The pure acid boils at 184° to 187°, and smells very much like common butyric acid; these are the properties of normal valerianic acid *, or, as it might conveniently be called, *pentylic acid*.

The following salts were prepared and analyzed:—

Silver pentylate, $C_5\,H_9\,O_2\,Ag$, is a white precipitate, which crystallizes from a boiling solution in woolly needles.

0·834 dried at 100° gave 0·4304 Ag.

Calculated for $C_5\,H_9\,O_2\,Ag$.	Found.
51·67 per cent.	51·6 per cent.

Barium pentylate, $(C_5\,H_9\,O_2)_2\,Ba + 1\frac{1}{2}\,H_2\,O$, obtained by neutralizing the aqueous

* Ann. Chem. Pharm. vol. clix. p. 58.

solution of the acid with barium carbonate, crystallizes from a hot concentrated solution in pearly scales.

0·5967 lost, on drying at 180°, 0·040 of water, or 6·7 per cent., the formula requiring 7·4 per cent. H_2O.

On igniting the dry residue, 0·3265 $BaCO_3$ were left behind, corresponding to 40·8 Ba, the calculated quantity being 40·4 per cent.

The salt obtained by spontaneous evaporation of the solution is, according to LIEBEN and ROSSI, anhydrous. I have therefore, after the publication of LIEBEN's and ROSSI's complete paper on normal valerianic acid, prepared this salt again; by spontaneous evaporation it was obtained in small plates and needles, which, after being dried in the air at the common temperature, lost at 180°, 2·6 per cent. of water, corresponding to $\frac{1}{2}H_2O$.

0·316 of the salt, dried at 180°, gave 0·1832 $BaCO_3$, corresponding to 40·3 per cent. Ba.

LIEBEN and ROSSI prepared their salt in the dry climate of Turin, whilst I worked in the damp air of Manchester, which may account for the differences.

Calcium pentylate, $(C_5H_9O_2)_2Ca + 1\frac{1}{2}H_2O$, obtained by neutralizing the acid with milk of lime, crystallizes on spontaneous evaporation in shining leaflets.

0·2958 lost, at 180°, 0·0293 H_3O, or 9·9 per cent., the amount required for the above formula being 10 per cent.

The dry residue left on ignition 0·111 $CaCO_3$, corresponding to 16·7 per cent. Ca, the calculated percentage being 16·5.

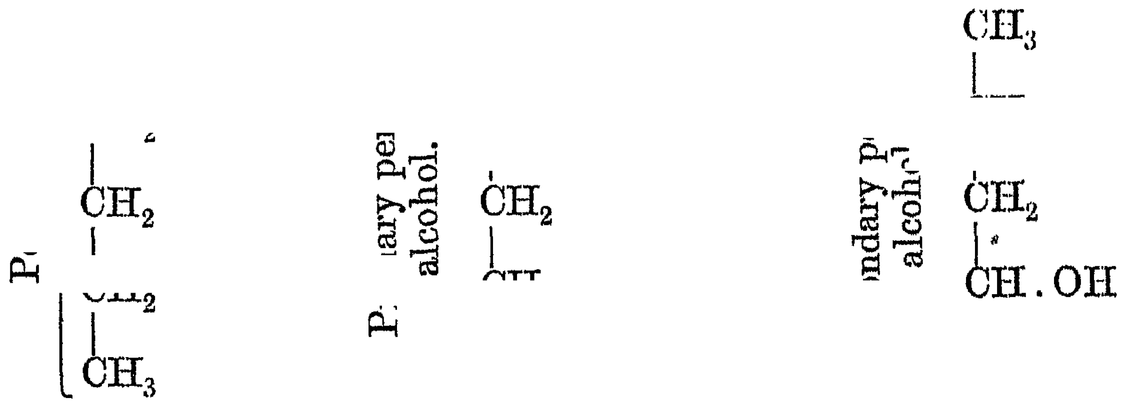
LIEBEN's salt contained only 1 vol. of water; but all other properties of these salts, which LIEBEN has described so very minutely, agree perfectly. From the cold saturated solution shining laminæ separate on heating, the greater portion of which dissolve again on cooling; on the other hand, a solution saturated at 100° gives on cooling to 70° a crystalline precipitate, which on further cooling nearly completely redissolves. I have repeated these experiments several times, following exactly LIEBEN's instructions, and with exactly the same results.

Besides pentylic acid and methyl-propyl ketone, I also obtained a small quantity of a high boiling liquid, having a pleasant smell like apples, which principally consisted of pentyl pentylate, as on decomposing it with caustic potash, pentyl alcohol, boiling at 134° to 137°, and pentylic acid were formed.

As there can be no doubt that LIEBEN and ROSSI's normal valerianic acid has the following constitution,

$$\begin{array}{l} CH_3 \\ | \\ CH_2 \\ | \\ CH_2 \\ | \\ CH_2 \\ | \\ CO.OH, \end{array}$$

it follows that the carbon atoms are grouped together in the same way in the pentane, which, therefore, belongs to that group of the paraffins which I have called "normal paraffins;" and the constitution of it and those of the alcohols derived from it are expressed by the following formulæ:—



The primary pentyl alcohol from pentane is identical with LIEBEN and ROSSI'S normal amyl alcohol; and the secondary alcohol is methyl-propyl carbinol, a compound obtained by FRIEDEL by the action of nascent hydrogen on methyl-propyl carbinol. The isoamyl alcohol obtained by WURTZ from isoamylene or ethyl allyl, appears to have the same constitution.

Normal Hexyl Hydride, or *Hexane*, C_6H_{14}.

This hydrocarbon was discovered by PELOUZE and CAHOURS in American petroleum. It is also found in cannel and boghead tar, and other coal tars. According to WARREN, petroleum contains, besides the hexane boiling at 68°, an isomeric hydrocarbon, which boils at 61°·3*. In the petroleum which I used this latter body was not present, the fractions between 40° and 68° being quite insignificant, and diminishing on each further distillation.

The monochlorides obtained from hexane boil between 120° and 130°, by far the largest portion distilling nearly constantly at 125° to 126°, as PELOUZE and CAHOURS have already observed. On acting upon them with potassium acetate, hexene boiling at 69° to 70° is obtained, and a mixture of the two hexyl acetates, which boil at 158° to 170°, and not, as PELOUZE and CAHOURS state, at 145°. The alcohols obtained from the acetic ethers were readily separated by fractional distillation into two portions, one boiling at 140° to 141°, and the other between 150° and 155°. As I have already stated, this separation of the alcohols is only very incomplete. I tried to obtain the pure alcohols by preparing the iodides and transforming those again in the alcohols. The iodide obtained from the portion boiling at 140° gave an iodide, the chief portion of which boiled, after fractional distillation, at 164° to 169°. On heating it with potassium acetate and glacial acetic acid to 100°, nearly half of it was decomposed into hexene and hydriodic acid, whilst the remaining portion was converted into an acetate boiling at 155° to 159°, from which the alcohol was regenerated, but could not be further examined, as it was lost.

* Chem. News, vol. xiii. p. 74, from Memoirs Amer. Academy.

The iodide prepared from the alcohol boiling at 150° to 155° was subjected to fractional distillation; the largest portion of it boiled constantly at 170° to 171°. On decomposing it with potassium acetate, $\frac{1}{6}$ was converted into hexene and $\frac{5}{6}$ into hexyl acetate, which boiled at 160° to 164°. The alcohol prepared from this acetate boiled now at 149° to 152°, and yielded on oxidation caproic acid, besides a not inconsiderable quantity of methyl-butyl ketone, from which it follows that it was still a mixture of primary and secondary hexyl alcohol.

The difference between the boiling-points of the primary and secondary iodide is too small to effect in this way a separation of the alcohols.

Methyl-butyl ketone, $\left.\begin{matrix} C\ H_3 \\ C_4\ H_9 \end{matrix}\right\} CO$, was obtained, as well as caproic acid, by oxidizing the mixture of the two hexyl alcohols, as described above. It is a colourless liquid with a pleasant smell, and boiling at 126° to 128°, which forms crystalline compounds with the bisulphites of the alkaline metals. It exhibits, therefore, all the properties of the acetone which ERLENMEYER and WANKLYN obtained by oxidizing methyl-butyl carbinol on the secondary hexyl alcohol obtained from mannite. On further oxidation it yields, like the latter compound, acetic and butyric acids, which were converted into the silver salts.

Calculated for silver butyrate						55·38	per cent.
1st fraction,	crystalline crusts,	0·792	gave	0·44	Ag=	55·56	per cent.
2nd	,, small needles,	0·2758	,,	0·153	Ag=	55·47	per cent.
3rd	,, small needles,	0·3695	,,	0·2335	Ag=	63·18	per cent.
4th	,, shining, flat needles,	0·966	,,	0·646	Ag=	64·85	per cent.
Calculated for silver acetate						64·67	per cent.

In order to throw light on the constitution of hexane, it was necessary to investigate closely the butyric acid obtained from it. To isolate this acid, the aqueous distillates obtained in the oxidation of the acetone were repeatedly distilled, when the butyric acid came over with the first portions, whilst the greatest part of the acetic acid was left behind. The aqueous solution of the butyric acid thus obtained was neutralized with milk of lime and evaporated on the water-bath. The butyrate separated as a crystalline scum on the surface, which was not wetted by water. The cold saturated solution of this salt, contained in a sealed tube, was heated to 70°–80°, when shining laminæ separated, which, on cooling, slowly but completely redissolved. This experiment was more than ten times repeated, always with the same results. The calcium salt possesses therefore all the characteristic properties of normal calcium butyrate.

The primary alcohol from hexane yielded as the product of its oxidation caproic acid, boiling at 200° to 205°. The silver salt is a white precipitate, which from a hot solution crystallizes in small needles.

(1) 0·5029 of this salt gave 0·2444 Ag.

(2) On evaporating the mother-liquor a second crop was obtained, 0·166 of which gave 0·0800 Ag.

Calculated for $C_6H_{11}O_2Ag$.	Found. I.	Found. II.
48·43 per cent. Ag	48·59	48·19

The calcium salt crystallizes from a hot concentrated solution in shining scales; by spontaneous evaporation it is obtained in ramified needles.

The most characteristic salt of this acid is the barium salt, which could not be obtained in the crystalline state, but which on evaporating an aqueous or alcoholic solution at a higher or at the common temperature, is always obtained as an amorphous, gum-like mass.

As the caproic acids of different origin have been so far very little studied, I have not investigated the salts of my acid more fully.

The oxidation products of the secondary hexyl alcohol or methyl-butyl carbinol, viz. *acetic acid* and *normal butyric acid*, are quite sufficient to prove that the hexane in petroleum is a normal paraffin, the constitution of which is expressed by the formula

$$CH_3—CH_2—CH_2—CH_2—CH_2—CH_3.$$

Hexane from Mannite.

ERLENMEYER and WANKLYN obtained this hydrocarbon by heating the secondary hexyl iodide obtained from mannite with zinc and water. I found it more convenient to act on the iodide with zinc and hydrochloric acid in the cold. To prepare it, a flask is filled with finely granulated zinc, the iodide is added, and then so much dilute hydrochloric acid that the zinc is not completely covered. The vessel must be immersed in cold water, or else a very violent reaction sets in. After a few hours the heavy iodide has disappeared and a light layer swims on the top, which, when subjected to distillation, was found to consist of a liquid boiling at about 70°, besides a smaller quantity of a body boiling at above 190°.

The liquid boiling at 70° had the odour of hexene, and the reaction with bromine showed that this body was present. In order to remove it, bromine was added drop by drop to the well-cooled liquid as long as its colour disappeared, and then hexane and hexene dibromide separated by fractional distillation.

The hexane from mannite, after being purified by treatment with nitric and sulphuric acids and rectification over sodium, is a mobile liquid, having the faint but characteristic odour of the paraffins. It boils constantly at 71°·5, and has at 17° the specific gravity 0·6630.

By acting with chlorine on its vapour a product is obtained, the greater portion of which boils at 126° to 128°·5, and a smaller at 128°·5 to 130°. Besides these, higher

chlorinated products had been formed, but only in a small quantity. From the liquid boiling between 126° and 130°, the alcohols were prepared and separated by fractional distillation into two portions; one, being about $\frac{2}{3}$ of the whole, boiled constantly at 140° to 141°; between 141° and 150° only a small quantity distilled, the remainder coming over between 150° and 153°. The products of oxidation were the same as those from the petroleum hexane, viz. *methyl-butyl ketone* and *caproic acid.*

The methyl-butyl ketone boiled constantly at 127°, and appears to be identical with that which ERLENMEYER and WANKLYN obtained from the secondary hexyl alcohol; on further oxidation it yields *acetic acid* and *normal butyric acid*, the presence of the latter being proved by the characteristic properties of the calcium salt.

The analyses of the silver salts, which were obtained as described above, gave the following results:—

Calculated for silver butyrate		. . . .		55·38 per cent.
1st fraction,	0·375	gave	0·1975	Ag=55·35 per cent.
2nd ,,	0·1241	,,	0·0685	Ag=55·19 per cent.
3rd ,,	0·1365	,,	0·079	Ag=57·88 per cent.
4th ,,	0·183	,,	0·118	Ag=64·48 per cent.
Calculated for silver acetate		. . . .		64·67 per cent.

The caproic acid, of which I obtained only a small quantity, had the same odour as that from petroleum, and the same boiling-point, viz. 201° to 204°.

0·1655 of silver caproate, which formed small needles, gave 0·0803 Ag=48·5 per cent., the calculated quantity being 48·43 per cent.

The calcium salt had the same properties as that from petroleum; the barium salt, however, was not amorphous, but crystallized most readily in plates or broad needles.

On decomposing the monochlorides with potassium acetate about equal quantities of the acetic ethers and hexene were formed, and by oxidizing the mixture of the two alcohols the quantity of acetone was double that of the caproic acid. Now, as the hexene was no doubt derived from the secondary chloride, it appears that by the action of chlorine upon the hydrocarbon $\frac{1}{6}$ is converted into the primary chloride, and $\frac{5}{6}$ into the secondary one.

The hexane of mannite and some of the derivatives boil a few degrees higher than the corresponding compounds from petroleum, and also the barium salts of the two caproic acids exhibit a decided difference. The hexane from petroleum is certainly not a pure compound; but whether this is the cause of the difference between the two hydrocarbons, or whether we have here a case of fine isomerism, for which an explanation has to be found, it is at present impossible to decide; the formation of acetic and normal butyric acids, however, proves that the hexane from mannite is also a normal hydrocarbon.

The products formed by acting with zinc and hydrochloric acid on hexyl iodide consist

of hexane, besides smaller quantities of hexene and a higher boiling liquid. The latter compound is a *dihexyl*, $C_{12}H_{26}$; it boils at 201°, and has at 17° the specific gravity 0·7758. It has the same boiling-point as the dihexyl obtained by the electrolysis of œnanthylic acid, which, as I shall show further on, is also a normal hydrocarbon. Whether these two hydrocarbons are identical or not has to be yet decided. The dihexyl from mannite might possibly have the following constitution:—

$$\left.\begin{matrix} C_4H_9 \\ C\ H_3 \end{matrix}\right\} CH—CH \left\{\begin{matrix} C_4H_9 \\ CH_3 \end{matrix}\right. .$$

By acting with zinc and hydrochloric acid upon hexyl iodide the following is the principal reaction:—

$$C_6H_{13}I + H_2 = C_6H_{14} + HI.$$

But besides that also the following decompositions occur:—

$$2C_6H_{13}I + Zn = C_6H_{14} + C_6H_{12} + ZnI_2.$$
$$2C_6H_{13}I + Zn = C_{12}H_{26} + ZnI_2.$$

Normal Dipropyl, C_6H_{14}.

To obtain this compound, allyl alcohol was first prepared from glycerine by TOLLEN'S method* and converted into propyl alcohol†, from which propyl iodide was obtained, boiling at 100° to 102°. On adding anhydrous ether and sodium to this iodide no reaction took place, either at the ordinary temperature or at the boiling-point of the mixture. To effect a complete decomposition, the substances had to be heated together in closed tubes to 140°–150°.

Pure dipropyl boils at 69° to 71°, and has at 17° the specific gravity 0·6630. It has, therefore, the same physical properties as the hexane from mannite, and from its formation it follows that it has also the same constitution. The quantity obtained was not sufficient to examine its derivatives.

Normal Heptyl Hydride, or Heptane, C_7H_{16}.

This hydrocarbon was first discovered by me in the light oils from cannel coal-tar‡, and afterwards I found it in large quantities in the petroleum from Pennsylvania§. WARREN has since shown that, besides this body, petroleum also contains an isomeric heptane, which boils at 90°·4‖; and my later researches have led me to the same conclusion¶. This lower-boiling heptane is always present, but in smaller quantities than the normal hydrocarbon. As the boiling-points of the two isomerides differ only by 10°, their complete separation is a very difficult and tedious process. By a very carefully

* Ann. Chem. Pharm. vol. clvi. p. 104.

† Ibid. vol. clix. p. 92.

‡ Chem. Soc. Journ. vol. xv. p. 419.

§ Chem. Soc. Journ. [2] vol. i. p. 216.

‖ Chem. News, vol. xiii. p. 74, from Mem. Amer. Academy.

¶ Proc. Roy. Soc. vol. xiv. p. 468.

conducted fractional distillation I succeeded in obtaining about one litre of normal heptane, 600 cub. centims. of which distilled at 97°·5 to 98°, and the remainder at 98° to 99°. According to PELOUZE and CAHOURS, the heptyl hydride from petroleum boils at 92° to 94°; but this body was a mixture of the two isomerides.

The heptyl chlorides boil at 145° to 160°, the principal fraction distilling, as I have formerly stated, at about 150°. The acetates which boil between 175° and 185° yielded, by acting on them with caustic potash, the two alcohols. The secondary heptyl alcohol boils at 160° to 162°, and the primary one at 170° to 175°. The former yields on oxidation *methyl-pentyl ketone*, $\left.\begin{matrix} C\,H_3 \\ C_5\,H_{11} \end{matrix}\right\} CO$, and the latter *œnanthylic acid*, $C_7\,H_{14}\,O$.

Methyl-pentyl ketone has a pleasant smell, like all these acetones; it boils at 150° to 152°, and combines with the bisulphites of the alkaline metals. By oxidizing it with chromic acid, acetic acid and pentylic acid are formed. The latter was isolated by repeated distillation of the aqueous solution of the two acids, the pentylic acid always coming over with the first portions, whilst the acetic acid is left in the residues, from which, by boiling them with silver carbonate, silver acetate was obtained, crystallizing in shining flat needles.

0·585 of silver acetate left on ignition 0·378 Ag=64·62 per cent.

The distillate containing the pentylic acid was neutralized with sodium carbonate, the solution evaporated, and the residue decomposed by sulphuric acid. The acid, after being dried with phosphorus pentoxide and freed by distillation from a little acetic acid, boiled at 183° to 187°, and smelt exactly like that obtained from pentane. The calcium salt separates as a crystalline precipitate on heating the cold saturated solution to about 70°, as well as on cooling down the boiling saturated solution to that temperature. The barium salt crystallized from the hot saturated solution in shining plates.

0·338 of this salt lost, at 180°, 0·0230 $H_2\,O$.

Calculated for $(C_6\,H_9\,O_2)_2Ba+1\frac{1}{2}H_2$.	Found.
7·4 per cent.	6·8 per cent.

The dry residue left on ignition 0·1835 $Ba\,CO_3$.

Calculated.	Found.
40·4 per cent. Ba	40·2 per cent.

The œnanthylic acid was found to be identical with that obtained from castor-oil. That from heptane boiled at 219° to 222°, and the acid prepared from castor-oil at 219° to 221°. On treating equal quantities of the two acids with water and barium carbonate, and evaporating the two solutions to exactly the same volume, thin iridescent plates appeared on cooling, which grew into large plates and broad needles; both salts are anhydrous.

(1) 0·467 of the salt from heptane lost, at 180°, 0·003 H_2O; the residue left on ignition 0·232 $BaCO_3$.

(2) 0·615 of the salt from castor-oil lost, at 180°, 0·003 H_2O, and the residue gave

	Found.	
Calculated for $(C_7H_{13}O_2)_2Ba$.	I.	II.
34·43 per cent. Ba	34·5 per cent.	34·6 per cent.

The mother-liquor of the barium salt from heptane gave with silver nitrate a white precipitate, which crystallized from boiling water in indistinct needles.

0·387 of this salt gave 0·178 Ag=46·0 per cent.

Calculated for $C_7H_{13}O_2Ag$=45·6 per cent.

As the secondary heptyl alcohol yields on oxidation *acetic acid* and *pentylic* or *normal valerianic acid*, it follows that the heptane is a normal hydrocarbon, having the constitution

$$CH_3-CH_2-CH_2-CH_2-CH_2-CH_2-CH_3.$$

Œnanthylic acid is consequently a normal acid, and dihexyl, which BRAZIER and GOSLETH obtained by the electrolysis of potassium œnanthylate, is therefore a normal hydrocarbon, to which I give the name *dodecane*, $C_{12}H_{26}$.

Normal Dibutyl or Octane, C_8H_{18}.

Normal butyl iodide, prepared by LIEBEN's method from butyric acid, and boiling at 128° to 130°, is easily acted upon by sodium in the cold. After a sufficient quantity had been gradually added, the mixture was heated for some hours, and then the hydrocarbon distilled off and purified by the well-known methods.

Dibutyl boils at 123° to 125°, and has at 17° the specific gravity 0·7032. These are exactly the properties of the octane which I have obtained from methyl-hexyl carbinol* and from sebacic acid†, and of that which ZINCKE prepared from his primary octyl alcohol‡. As the properties of these hydrocarbons of different origin agree so very closely, it appears almost certain that they are identical. If so, the dioctyl, $C_{16}H_{34}$, which ZINCKE obtained as a by-product in preparing octane is also a normal paraffin, which I call *hecdecane*.

We are now acquainted with the following normal paraffins or homologues of marsh-gas, in which the carbon atoms are linked together in a single chain§.

* Proc. Roy. Soc. vol. xvi. p. 376.

† Ibid.

‡ Ann. Chem. Pharm. vol. clii. p. 1.

§ Comp. Proc. Roy. Soc. vol. xix. p. 488.

Boiling-points.

		Mean found.	Calculated.	Difference.
CH_4	Methane			
C_2H_6	Ethane			
C_3H_8	Propane			
C_4H_{10}	Butane	1°	1°	
C_5H_{12}	Pentane	38	38	37
C_6H_{14}	Hexane	70	71	$33=37-4$
C_7H_{16}	Heptane	99	100	$29=33-4$
C_8H_{18}	Octane	124	125	$25=29-4$
$C_{12}H_{26}$	Dodecane	202	201	4×19
$C_{16}H_{34}$	Hecdecane	278	278	14×19

In calculating the boiling-points, it was assumed, as appears to be the case, that the difference decreases regularly by 4 until it reaches the well-known difference 19°.

VIII. *The Myology of the Cheiroptera.* *By* ALEXANDER MACALISTER, *A.B., M.B. Dubl., Professor of Zoology in the University of Dublin. Communicated by Dr.* SHARPEY, *Sec. R.S.*

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THE aberrant forms and remarkable habits of the animals composing this order, so divergent from the general mammalian type, render the study of their myology a subject of the deepest anatomical interest; and yet it is singular how little attention has hitherto been directed to its investigation. Thus in the article "Cheiroptera" in the 'Cyclopædia of Anatomy and Physiology,' the muscular system is passed over unnoticed; and in another standard work, Professor OWEN'S 'Comparative Anatomy of Vertebrates,' the only fact noticed regarding the muscles of the Bats is their deep red colour (vol. iii. p. 1). No extensive series of observations has hitherto been made on this subject; a few species only have been dissected with care, and these dissections have not even been compared with each other. CUVIER, MECKEL, KOLENATI, HUMPHRY, and AEBY are among the only authors who have published records of their researches, and not more than four or five species have been made the subjects of description.

On examining some of the store jars in the Museum of the Dublin University, I found some specimens of Bats which proved on examination to be in very good dissectable condition. During the past summer I made a very careful series of dissections of these, and have from them compiled the present Monograph. The number of perfectly new and remarkable facts which have, in the course of my examinations, been observed and recorded, will, I think, fully justify me in publishing a detailed account of my dissections.

The small size of some of these animals rendered the dissection a matter of difficulty, as in many cases I was obliged to use a simple dissecting-microscope. For the same reason I was not able to use the balance with any degree of comfort, as a means of comparing the relative development of muscles in different species; I was, indeed, compelled to give up the use of this aid to investigation, as, from the small sizes and the necessary difficulty in raising entire muscles with the degree of absolute perfection requisite in the comparison of such small weights as grains or fractions of grains, the work became almost hopelessly tedious; and thus I have very little additional light to throw upon this interesting subject, whose study has been begun by Professor AEBY in Basel and Professor HAUGHTON in Dublin.

The species referred to in this paper are the following:—of the Pteropidæ, *Pteropus edulis, medius*, and *Edwardsii, Macroglossus minimus, Eleutherura marginata, Cephalotes Pallasii, Cynonycteris amplexicaudatus*; of the Rhinolophidæ, *Rhinolophus ferrum-*

equinum, *diadema*, and *speoris*, *Megaderma lyra*; of the Phyllostomidæ, *Artibeus jamaicensis* and *Vampyrops vittatus*; of the Vespertilionidæ, *Vespertilio murinus*, *Vesperugo pipistrellus*, *Scotophilus hesperus*, *Noctulina altivolans*, *Plecotus auritus*, *Synotus barbastellus*. These nineteen species will be seen to represent fully the variety of forms included in the order. For purposes of comparison I have also dissected *Pteromys volans* and *Galeopithecus*.

As might be expected, a strong family likeness pervades the entire series; the differences are chiefly slight, though often suggestive, varieties of detail.

These do not form in any species a continuous sheet or panniculus, but consist of separated bands or slips in several regions, the principal of which are the following:—

1. Platysma myoides superior (Plate XIII. fig. 4, *b*), which arises from the ramus of the mandible, from the integument over it, and from the angle of the mouth, usually continuous with the depressor anguli oris; passing backwards and downwards it is inserted into the anterior margin of the occipito-pollicalis (to be afterwards described), to which, however, it lies superficial. This muscle is large and strong in *Eleutherura*, *Macroglossus*, and *Pteropus*, weaker in *Cephalotes* and the Phyllostomidæ; lies distinctly superficial to the occipito-pollicalis in the last named; and in the species of *Vespertilio*, *Vesperugo*, and *Scotophilus* it scarcely seems to be connected to it: it is very feeble in *Plecotus* and *Megaderma*. This muscle is the representative of the ordinary platysma of Man and the Chimpanzee; it is figured as the cervico-fascien by CUVIER and LAURILLARD in *Pteropus*, and is described as the first part of the platysma by Professor HUMPHRY (Journal of Anatomy and Physiology, vol. iii. p. 299, 1869).

2. Platysma myoides medius (Plate XIII. fig. 4, *c*) is a band of very variable strength, well marked in *Cephalotes*, *Pteropus*, and *Eleutherura*, feeble in *Macroglossus*, and absent in *Vampyrops* and *Artibeus*; it arises from the middle line of the neck for its lower half, in front, passes outwards and backwards over the sterno-cleido-mastoid to be inserted with the last. In the Pteropidæ it is not connected to the last described except at its insertion, but in *Plecotus* they form a continuous very feeble sheet; and the same is the case in the Rhinolophidæ, in which it is extremely thin. In *Cephalotes* and *Eleutherura* the muscles of both sides are continuous in the middle line, and form a strong, thick, red mesial band passing from shoulder to shoulder above the clavicles. This is the third part of the platysma of Professor HUMPHRY (*loc. cit.*).

3. Platysma myoides inferior (Plate XIII. fig. 4, *d*) arises from the integument over the middle of the sternum, passes upwards and outwards to be inserted in common with the upper and middle platysmata. In *Pteropus* it arises opposite the lower part of the sternum; in *Cephalotes* it is narrower and arises higher up. In this genus its fibres are not so oblique as those of the pectoral, and in their course they strongly remind one of the rectus sternalis in some of its forms, thus offering some shadow at least of evidence in favour of the theory put forward and supported by WILDE, HALLET, and TURNER, that

this muscle is of the nature of platysma. I have not been able, in any species of the Vespertilionidæ, to demonstrate any connexion between this muscle and the occipito-pollicalis; in these it seems to end in the integument of the top of the shoulder; it is very narrow in *Vampyrops vittatus*, and is similar in its arrangement in *Artibeus*. In all cases its origin was purely cutaneous, and in none had it any connexion with the sternal carina, as was found in *Pteropus Edwardsii* by Professor HUMPHRY (*l. c.* p. 299).

4. In *Cephalotes Pallasii* a thin nuchal band of platysma existed (Plate XV. fig. 2, *f*), passing from the mesial line of the lower part of the back of the neck to join the occipito-pollicalis. I have not detected a similar band in any other species except in *Pteropus edulis*, in which it was very large and extended up to the occiput, covering, but quite separate from, the occipito-pollicalis.

5. Dorsi patagialis (Plate XIII. fig. 1, *b*).—This name I would suggest for a part of the panniculus which I have found in all the species as a fine triangular muscle arising from the integument in the mesial line of the back opposite the lowest dorsal and uppermost lumbar vertebræ, and passing upwards and outwards to the axilla, where it was inserted into the skin of the plagiopatagium*; it lay superficial to the latissimus dorsi, from which it is separated by the superficial dorsal fascia. In *Artibeus* and *Vampyrops* this is strong and red; it is also large in *Noctulina* and the Pipistrelle, in the former of which a slip of it rises to the coracoid process, into the internal edge of which it is inserted. In *Pteropus* it is especially large, particularly in *Pt. edulis*. In *Megaderma lyra* a slip of it runs into the lower margin of the teres major, and another was inserted into the humerus at its upper point of trisection. In *Eleutherura* this muscle coexists with a separate coraco-cutaneous muscle, and is inserted into the skin of the axilla. Neither HUMPHRY nor CUVIER make any reference to this muscle; the former merely mentions in general terms the existence of a few fibres in this locality.

6. Coraco-cutaneus (HUMPHRY) I found as a separate muscle in *Eleutherura*, arising from the coracoid process internal and anterior to the coraco-brachialis, from which it is separated by the brachial plexus; crossing the axillary artery this muscle is inserted into the skin of the axilla. In *Noctulina altivolans* a slip of this muscle exists as an offshoot from the dorsi-patagialis, as above described, crossing the brachial plexus. In *Pteropus Edwardsii* and *medius*, as described by Professor HUMPHRY, it is distinct and extends in the plagiopatagium to the lower margin of that fold. Several fibres run parallel to this band which have no bony attachment. Of the same nature as the coraco-cutaneous is the humero-cutaneous muscle which exists in *Noctulina*, arising from the inner border of the humerus three lines above the elbow-joint, passing downwards to be

* To avoid periphrasis, I will use the names recommended by KOLENATI for the different parts of the wing-membranes:—*propatagium* being the part in front of the elbow; *plagiopatagium* that from the extensor aspect of the fore limb to the hinder limb and extending to the little finger; *uropatagium* that between the hinder limbs, including the tail; *epiblema* the membrane attached to the spur; *dactylopatagium brevis* the web between the thumb-root and the index, *d. minus* between index and middle, *d. longus* between middle and ring, *d. latus* between ring and little fingers.

lost in the plagiopatagium; it is a very slender muscle-bundle in this animal, and cannot be traced for more than half an inch; it overlies the pronator teres. In *Cephalotes* this also exists, and it makes a conspicuous ridge, as may be seen in ST.-HILAIRE's figure of this species (Annales du Muséum d'Histoire Naturelle, tom. xv. pl. 7). I was not able to make out accurately in this species whether any fibres came from the biceps or no, as Professor HUMPHRY has so well described in *Pteropus*; certainly the largest part of its fibres arise from the humerus.

7. Cutaneo-pubic (HUMPHRY) I could only separate in the larger species as an expansion of fine muscular fibres from the neighbourhood of the pubes; these ascended and passed backwards in a narrow stream, which ended over the great pectoral at its shoulder end by being attached to the skin. I could only find it in the Phyllostomine and Pteropine Bats and in the Noctule. I could not trace it to a bony attachment, but Professor HUMPHRY has traced it to the fore part of the pelvis. The same anatomist traced in *Pteropus* one fascicle of the muscle to the lower margin of the plagiopatagium.

8. Femoro-cutaneus (HUMPHRY) was only found in the *Pteropi*, *Macroglossus*, and *Artibeus*, arising from the tibial side of the thigh (in my specimen not so low down or so purely from the bone as Professor HUMPHRY describes it to have been in his *Pt. Edwardsii*); passing in a radiating manner upwards and inwards, it is inserted into the integument of the middle line of the back, over the gluteal muscles, and as high as the middle of the lumbar region.

9. Ischio-cutaneus (Plate XIII. fig. 1, *e*), thin and band-like, I found in *Eleutherura marginata* passing in the uropatagium from the ischium to the integument over the calcaneum and dorsum of the foot. Professor HUMPHRY found the same in the *Pt. Edwardsii*. It is possible that this may be the representative of the biceps flexor cruris diminished to a rudiment. I did not find it in any other species.

Other cutaneous fibres here and there were found in the patagial membranes of other species. Professor KOLENATI has found in some species one of these fascicles between the pectoralis major and the serratus magnus, and inserted into the plagiopatagium; this he calls the corrugator plagiopatagii (Flughautrunzler). In the *Myotus murinus* he figures this (Allgemeine dutsche naturhistorische Zeitung, iii. Band, 1ste Heft, p. 10, Taf. III. *a**). I have not, however, been able to make out, in any species except *Noctulina altivolans*, any muscular band of sufficient size to merit a distinct name in this position. Single bands of fibres do run in this and other directions in the membrane, but they are not worthy of distinct names.

10. At the close of the muscles of this group we may place one of the most remarkable of the muscles found in the organization of the Bat, the occipito-pollicalis of KOLENATI (Plate XIII. figs. 1, 2, 4 & 5, *a*, Plate XV. figs. 1, *g*, & 2, *c*), although its claim to be regarded as a muscle of this group rests on a very slender foundation. This muscle arises from the superior curved line on the occipital bone for a varying extent; in *Cephalotes Pallasii* it extends for nearly the whole length of the ridge, in *Noctulina* it is attached to its outer third, in *Eleutherura* to its outer fifth, in *Artibeus* to the

middle third, in *Pteropus* and *Macroglossus* to the inner half, in *Rhinolophus diadema, speoris,* and *ferrum-equinum* to the outer half or third; it is very small in the *Megaderma*: the fibres pass outwards from this origin, extend along the free edge of the propatagium to be inserted into the base of the terminal phalanx of the pollex. The muscular fibres are deeper in colour than those of the rest of the platysma, and vary in the different species in the distance to which they extend. In *Vespertilio murinus, Synotus barbastellus, Macroglossus,* and *Plecotus* they continue for two thirds the length of the entire course; in the Phyllostomine Bats and *Pteropus* nearly one half is muscular; in all the muscle ends in a highly elastic cord, which continues on nearly to the insertion. A short distance above the thumb, a few muscular fibres are superadded to this. Professor HUMPHRY found in his specimen of *Pteropus Edwardsii* that the whole cord resolved itself into a second fleshy belly; in *Cynonycteris* it had a large inferior fleshy belly; in *Pteropus edulis* its origin was under cover of the nuchopatagial muscle. In all, immediately on the cessation of the secondary muscular fibres, the cord ceases to be elastic and becomes an ordinary tendon.

At its commencement in *Cephalotes* this muscle receives a few fibres from the occipito-frontalis, and on the left side of the specimen dissected a muscular band from this muscle passed to the back of the concha auriculæ (Plate XV. fig. 2, *e*). In the *Eleutherura* this muscle and the occipito-frontal are even more closely connected. In *Rhinolophus diadema* the muscle arises under cover of the retrahens aurem, and its fleshy fibres do not continue beyond the shoulder. At first the glandular and fatty masses associated with the thymus separate it from the cervical trapezius and from the platysma. Its fibres are perfectly free from those of any muscle at first, until it reaches the middle of the shoulder, where the superior middle and inferior parts of the platysma are inserted into it. The nature of this muscle has been the subject of difference of opinion. Professor KOLENATI figures it as a special muscle under the name which I have adopted (Sitzungsberichte der Königlich. böhmischen Gesellschaft der Wissenschaft, 1847, and the Allgemeine deutsche naturhist. Zeitung, Dresden, iii. Band, 1 Heft, p. 9, 1857); he also calls it extensor propatagii, or *Hinterhaupts-Daumenmuskel*. CUVIER and LAURILLARD figure it as the dorso-occipitien, and HUMPHRY describes it as the second piece of the platysma. CUVIER (see HUMPHRY, p. 304) supposes it might possibly be a modified part of the trapezius; and MECKEL, in criticising CUVIER's description of the trapezius in Bats, says, "mais il existe en outre un muscle longitudinal qui est tout-à-fait séparé du trapezius par le thymus, ce muscle prend naissance à la crête occipitale, se porte en bas et en dehors à l'apophyse acromien et au grand pectoral avec lequel il s'unit antérieurement. Cette disposition est la première trace d'une faible séparation de la partie antérieure du trapèze" (Traité d'Anat. Comp. traduit par RIESTER et SANSON, vol. vi. p. 219). MECKEL's failure in the tracing of this muscle he redeems subsequently in speaking of the muscles of the pollex; it is plain, however, that in both places he is speaking of different aspects of the same muscle.

I think we have sufficient reason to coincide with the theory thus proposed bb MECKEL,

that this muscle is the modified occipital trapezius, because:—1st, it is supplied by the spinal accessory nerve, as I have been able to demonstrate in *Eleutherura* and *Cephalotes*, as well as in *Megaderma*; this is the source from which the occipital trapezius draws its nervous supply in Man; had it been platysmal it would have been supplied by the branches of the cervical plexus; 2ndly, it has a more definite origin than any part of the panniculus; 3rdly, the spot of its origin is exactly that from which the trapezius should arise; 4thly, it is redder than the rest of the superficial muscles; 5thly, it is analogous in function to the tensor plicæ alaris of the bird, which is the modified acromial deltoid, retaining its origin and altered in its insertion; this seems to be a similarly modified occipital trapezius; 6thly, there is no trace of any other occipital trapezius, and the muscle is always highly developed. Against this view is its arrangement in *Cephalotes* and *Eleutherura*, in which it is actually joined to the cutaneous muscles at its origin. The superadded muscular fibres in the forearm may represent an accessory palmaris, a palmaris brevis, or a flexor digitorum sublimis.

The uses of these muscles are very obvious; the occipito-pollicalis raises and abducts the thumb and makes tense the dactylopatagium brevis. If the triceps cooperate with it, it makes tense the propatagium; the three parts of the platysma cooperate with it and assist it. The other muscular bands either contract the wing-membrane or move the skin. As a general rule the disposition of the cutaneous muscles will be seen to resemble closely the arrangement of the panniculus in the higher Carnivora.

Facial Muscles.

This group of muscles is very well developed among the Bats, and though paler than the body- and limb-muscles, yet they are redder than usual.

The occipito-frontalis (Plate XIII. figs. 2, *d*, & 6, *c*, *d*) in all is quadrigastric, the occipital bellies being quadrilateral, parallel, and close together; this muscle arises from the inner third or half of the superior occipital line. In *Plecotus* the bellies are very short and thick, in *Cephalotes* they are thin and weak; these soon end in the epicranial aponeurosis, from which the anterior bellies spring. In *Plecotus* the aponeurosis begins on the level of the base of the ear, and the frontal bellies are inserted into the integument of the forehead and into the procerus nasi; the anterior bellies are confluent in *Noctulina*, as well as in the *Rhinolophus diadema* and *speoris*, and are barely separable in *Vampyrops* and *Artibeus*, in both of which the posterior bellies have a wide origin. In these also the epicranial aponeurosis is narrow, not exceeding in its length one half of the width of the ear-cartilage; the frontal bellies are enormous in *Cephalotes*, very small in *Megaderma*, moderate in the Pteropidæ.

The size of the ear-muscles, though in general they bear some proportion to the development of the auricle, cannot be said to obey any regular law; for while in *Plecotus* and *Synotus* they are larger than in *Vespertilio*, *Scotophilus*, or the Pipistrelle, yet in *Rhinolophus* and *Eleutherura* they are nearly as large as in *Megaderma lyra*. The extrinsic muscles are the usual three.

1. Retrahens aurem (Plate XIII. fig. 7, *b*) in *Plecotus* is strong and prominent, arising from the occipital line, passes outwards to be inserted into the back of the concha; a few fibres join the muscle of one side to its fellow of the opposite across the mesial line. In *Synotus* its arrangement is similar; in *Vespertilio*, *Vesperugo*, and *Noctulina* it is thinner and wider, and is attached to the outer part of the occipital bone. In *Pteropus* and *Macroglossus* it is also thin, wide, and triangular. In *Vampyrops* it is double (Plate XIII. fig. 6, *a*, *b*), the lower muscle starting from the occipital protuberance, the upper from the curved ridge external to the occipito-pollicalis. In *Cephalotes* it is small and thick; on the left side in my specimen a band came from the occipito-pollicalis to join this muscle, lying superficial to the sterno-cleido-mastoid. In *Megaderma* the retrahens consists of three slips (Plate XIII. fig. 2, *b*, *c*), arising in common with the occipito-frontalis, of which the middle is the longest and the inferior the shortest. In *Myotus* it is still further fasciculated; Kolenati found it in five bundles.

2. Attollens aurem (Plate XIII. fig. 6, *c*) in *Vampyrops* and *Artibeus* is wide and thin; most of its fibres run downwards and forwards; it arises from the epicranial aponeurosis. In *Megaderma* it is wider and thicker, very large in *Plecotus*, and attached from the occipital curved line to the anterior margin of the epicranial aponeurosis; not quite so extensive in the other Vespertilionine Bats. In *Cephalotes* it arises from the mesial line of the scalp, overlying the epicranial aponeurosis (Plate XV. fig. 1, *k*).

3. Attrahens aurem (Plate XIII. fig. 5, *f*) is very large in *Megaderma*, and arises from the supraorbital ridge as well as from the zygomatic arch; it is inserted into the anterior surface of the concha and tragus; in *Plecotus* and *Synotus* it is small and thick. In *Noctulina altivolans* it consists of two parts, one normal from the zygomatic arch, the other a transverse band on the forehead passing from the one ear to the other above the supraorbital ridges, and over the anterior bellies of the occipito-frontales. In *Vampyrops* the muscle is strong and its lower border rounded. In *Cynonycteris* it is single and much weaker, and it is moderate in development. In *Artibeus jamaicensis*, in *Pteropus*, and the Kiodote (*Macroglossus minimus*) it consists of a thin sheet of muscle overlying and attached to the temporal aponeurosis (Plate XIII. fig. 3, *e*). In *Cephalotes* its origin is from the zygomatic process of the temporal bone under the zygomatic muscle; it passes upwards and backwards to the ear, forming a strong band of fibres.

In *Plecotus* Kolenati has found a special depressor tragi passing from the concha to the tragus, which it depresses; this corresponds to the tragicus of the human ear; this exists in the Horseshoe Bats and in *Megaderma lyra*, but I found it in no others.

The nose has one large pair of muscles in every species, the procerus nasi (Plate XIII. fig. 6, *e*) (pyramidalis would be a misnomer in every case); this varies in size, being small and indistinctly joined to the frontalis in *Plecotus*, larger in the Barbastelle (*Synotus*), inseparable from the frontalis and small in *Megaderma*, enormously large and thick and with a special frontal origin in *Rhinolophus diadema*, *speoris*, *ferrum-equinum*, and *hipposideros*, also large, but with no separate origin, in *Cephalotes*. In *Vampyrops vittatus* it is likewise large, and has a special bony attachment. In *Artibeus* it is

inserted into the base of the nose-leaf, and in *Cynonycteris* is exceedingly feeble in its development.

In *Noctulina altivolans* I found two small muscular bands which represented the dilator naris, anterior and posterior; I have not found them in any other Vespertilionine or Pteropine species. In the nose-leaf of *Artibeus* the same were present, but were much larger, passing from the integument of the side of the face to the nose-leaf; in that of *Megaderma* these were much more feeble.

In *Rhinolophus speoris* the first-named pair of nasal muscles are on either side of the pouch, and thus can constrict it.

The eye-muscles are also very simple; the orbicularispal pebrarum (Plate XIII. fig. 3, *d*, & 5, *h*) is a single muscular ring attached to a tendo-oculi, and does not present any variation in any of the species. In *Vampyrops* a few fibres from its upper surface pass upwards and backwards into the anterior belly of the occipito-frontalis, making a sort of corrugator supercilii (Plate XIII. fig. 6, *f*); an arrangement like this also exists in *Megaderma*, but I did not find it in any of the others. No other external eye-muscles were traced.

The muscles of the mouth are usually well developed; the orbicularis in all is a single muscular ring into which the other muscles are inserted; zygomaticus minor I only found in *Cephalotes* (Plate XV. fig. 1, *g*) as a small fascicle above the major from the zygoma to the angle of the mouth.

The zygomaticus major in *Vampyrops* (Plate XIII. fig. 6, *j*) exists as a wide band from the zygomatic arch to the angle of the mouth; in almost all the other species, however, it existed as an auriculo-angular muscle, passing from the front of the ear to the angle of the mouth; this is the case in the Noctule, Pipistrelle, *Cephalotes* (Plate XV. fig. 1, *h*), *Megaderma* (Plate XIII. fig. 5, *e*), and others. In *Macroglossus* (Plate XIII. fig. 3, *h*) and *Pteropus* it is a true zygomatic with no ear-connexion.

A levator anguli oris (Plate XIII. figs. 3, *f*, 5, *o*, 6, *i*) is present in all, arising from the maxilla in front of and beneath the infraorbital ridge; in *Macroglossus* this joins the zygomaticus. A depressor anguli oris and depressor labii inferioris combined exist in the lower lip, arising from the mandible and inserted into the orbicularis (Plate XIII. figs. 3, *j*, 5, *l*, 6, *m*).

Levator labii superioris alæque nasi in *Megaderma* (Plate XIII. fig. 5, *i*, *j*) is a remarkable and complex muscle, consisting of two slips crossing each other, the more superficial passing from above and in front of the inner angle of the eye to the upper lip, the deeper arising external and a little inferior to the former, and passing more horizontally to be inserted into the ala of the nose and the basal lobes of the leaf. This muscle in *Vampyrops* is represented by a single band (Plate XIII. fig. 6, *h*), starting from the inner side of the orbit and nasal bone. In the Pteropine Bats this muscle is thin, and has no nasal attachment (Plate XV. fig. 1, *e*).

The muscles of mastication are very variable in degree of development. The temporal is small in *Plecotus*, larger in *Synotus*, still larger in *Noctulina*, and proportionally largest in *Pteropus edulis*. The masseters are bilaminar in all, proportionally largest in

Pt. Edwardsii, then in *Noctulina*, and smallest proportionally in *Cynonycteris*. The buccinator is weakest in *Pteropus*, and proportionally strongest in *Myotus* (*Vespertilio*) *murinus*. The pterygoids, especially the externals, are particularly small in all the species.

Muscles of the Neck.

On raising the integument of the neck the first structures exposed are the several parts of the platysma already described, then several large glandular and fatty masses, connected with the large thymus of these animals. The salivary glands are very large in the frugivorous Bats, especially the parotid, which extends into the anterior cervical triangle; the submaxillary, though smaller, yet is a large gland, and much rounder and more definite than the former. Below these the following muscles are brought into view:—Sterno-mastoid, in *Plecotus* and the other Vespertilionine Bats, as well as in *Megaderma* (Plate XIII. fig. 5, *c*) and *Pteropus*, is a large single indivisible muscle arising from the episternum and sterno-clavicular ligaments, and inserted into the paroccipital and supraoccipital bones; in *Pteropus edulis* it extends as far inward as the occipital protuberance. In the species of *Rhinolophus*, *Pteropus funebris*, *Eleutherura*, and *Macroglossus*, as well as *Cephalotes* (Plate XV. fig. 1, *l*, *m*, *n*), *Vampyrops*, and *Artibeus*, the sterno-mastoid is double, the superficial part being as described above, and covering a deeper band smaller in size, which arises fleshy from the sternum, and is inserted by a narrow tendon into the paroccipital process alone. Both CUVIER and MECKEL speak of this muscle as single, and as having no trace of a clavicular origin.

Cleido-mastoid is a muscle whose existence in the Bats has been denied by CUVIER and MECKEL; yet it exists and is often moderately strong, as in *Noctulina*: it is usually perfectly separate from the sterno-mastoid, more vertical than which it lies, and in *Vampyrops* the spinal accessory nerve intervenes; it is inserted along with the deep sterno-mastoid into the paroccipital process; it is exceedingly small in *Megaderma*, *Cephalotes*, and *Eleutherura*, larger in *Rhinolophus diadema* and *speoris*; in the Pipistrelle it is only one third the size of the sterno-mastoid; in *Pteropus* it is even less, and its upper third is tendinous, and inserted into the tip of the paroccipital. No trace of a cleido-occipital exists in any of the species examined.

Sterno-hyoid (Plate XIII. fig. 8, *i*) is broad, flat, and thin, passing from the posterior aspect of the sternum to the os hyoides. In my specimen of *Noctulina* it was united to the omo-hyoid in a manner to be described hereafter. A tendinous inscription exists in most of the Vespertilionine Bats; I found none either in the Pteropine or Phyllostomous species, while in *Rhinolophus* the sterno-hyoid is narrow, and presents nothing remarkable. In *Noctulina* the mylo-hyoid was covered by a layer of longitudinal fibres, constituting a mento-hyoidean muscle. Of the other laryngeal and tongue-muscles there are no facts of sufficient interest to deserve special record. The styloid muscles are large and strong, especially the stylo-glossus, which passes as usual from the stylohyal bone to the side of the base of the tongue.

Digastric (Plate XIII. fig. 8, *c*, *d*) in the Vespertilionine Bats is a simple one-bellied depressor of the mandible, extending to the middle third of the ramus, and largest pro-

portionally in *Noctulina*. In the Pteropine Bats it is of very large size, especially in *Cephalotes*; in *Megaderma lyra* and *Pteropus edulis* it shows a very remarkable and interesting feature, namely, a tendinous inscription obliquely crossing it opposite the angle of the jaw. This is very interesting in a morphological point of view, as the muscle is not protracted further forward than usual in these species; it shows that the two bellies of the truly digastric type of depressor of the mandible (such as is found among the Primates and the Rodentia) are represented in this and other orders by the single-bellied muscle, and that it is not simply a homologue of the posterior belly. Thus from the single-bellied muscle of the Carnivora and Cetacea &c., we have the intermediate step of the digastric intersected by an inscription leading us to the truly biventral form in the higher mammals.

The omo-hyoid is a slender and distinctly biventral muscle in the Vespertilionidæ. In the Phyllostomine Bats it is large, and with scarcely any trace of a tendinous intersection. In *Macroglossus* it passes from the suprascapular ligament to the hyoid bone, and, as in the other Pteropine Bats, it is digastric, but its central tendon is very short. In my specimen of *Noctulina* there is a muscular band arising from the middle of the clavicle and joining the sterno-hyoid muscle at a point about midway between the origin and insertion of that muscle; immediately beyond the point of union a tendinous line existed in the combined sterno-hyoid and omo-hyoid muscles; no other omo-hyoid existed in this species, and this arrangement was present on both sides. This method of attachment in the omo-hyoid has hitherto only been known as an anomaly in human anatomy, and as such I have described it (Trans. Royal Irish Academy, vol. xxv. 1871, p. 22).

The three scalenes exist in the Bat as MECKEL has described. The anterior is very small, and in *Vampyrops* ascends to the transverse process of the second cervical vertebra; the medius and posticus are united at their origins, separate at their insertions. MECKEL says they are arranged as in the Carnivora; the posticus does not extend below the fourth rib.

The other deep muscles of the neck, longus colli, longus atlantis, recti capitis antici, major et minor, displayed no points worthy of special notice.

Muscles of the Thorax.

This group of muscles is of deep interest, as its elements are concerned in the action of flying.

Pectoralis major (Plate XV. fig. 1, *s*) is in two parts in all species, but they vary slightly in their degree of separability; it is distinctly cleft in the Pteropine Bats into a clavicular and a sternal muscle, not quite so separable in the Phyllostomidæ, separate at origin but combined at insertion in the *Plecotus*, with little more than a distinct trace of division in *Vesperugo*, and nearly completely severed in *Vespertilio*, *Noctulina*, and *Scotophilus hesperus*. The sternal part is undivided and of enormous size, arising from the whole length of the sternum, except the xiphisternum, from the anterior sterno-clavicular ligaments, and it is inserted into the pectoral crest on the humerus.

This muscle is proportionally largest in the Vampyres, especially in *Artibeus*; is short and thick in *Plecotus* and the Pipistrelle. It has in general, properly speaking, no clavicular origin, as Professor HUMPHRY states; but that author does not notice the origin from the sterno-clavicular ligament and the somewhat kidney-shaped epicoracoid. This enormous muscle is by far the largest in the body of the Bat. In *Megaderma* a few fibres are attached to the sternal end of the clavicle, and the entire muscle is much thinner than in the Vampyres. The degree of separation existing between this muscle and the clavicular deltoid is very variable; they are perfectly distinct in the species of *Rhinolophus*, especially *R. diadema*; in *Eleutherura* they are conjoined; nearly so in the *Pteropus Edwardsii*; quite separate in *Pteropus edulis* and in *Megaderma*. In the Vespertilionidæ, as remarked by MECKEL, they are combined. In my specimen of *Pteropus edulis*, which was 36 inches in expanse of wing, this muscle weighed an ounce and one tenth.

The second part of the great pectoral, or the pars clavicularis, is variable in size and separateness, completely covered by the sternal part and small in *Cephalotes*; it arises from the anterior sterno-clavicular ligament and the inner half of the under border of the clavicle; it is inserted above the sternal pectoral into the pectoral crest; it lies on the costo-coracoid membrane and the coracoid process. In *Vampyrops* it is, at its commencement, completely under cover of the sternal part, but at its insertion it is the more superficial of the two. In *Macroglossus* and *Pteropus* this portion, though in its course and termination on a plane posterior to the sternal part, is less covered at its origin, and passes over the coracoid process. In these it arises from nearly the whole length of the clavicle (two thirds in *Pteropus medius*, one third in *Edwardsii*, Humphry, even less in *Pteropus edulis*); its lower surface is flat and fleshy where it lies on the coracoid, from which it is separated by loose areolar tissue; but no bursa intervenes, and the relation of the parts in nowise partakes of the nature of a pulley. This portion in the *Plecotus* overlaps the sternal part for one half, and the same is the case in *Vespertilio*. In *Megaderma* it is more distinctly separate than in any other species, the anterior cutaneous nerve intervening between it and the pars sternalis; in this species it has much the appearance of the human anomaly pectoralis minimus described by Professor WENZEL GRUBER, of St. Petersburg; it arises from the clavicle, sterno-clavicular ligament, and from the cartilage of the first rib; the insertion is by a special round tendon into the pectoral crest of the humerus.

The nature of this second part of the great pectoral has been a subject of difference of opinion. CUVIER, in the 'Leçons Orales,' describes the great pectoral as tripartite, and regards this as its second part. MECKEL describes the great pectoral as consisting of a superficial and two deep portions; the first of these, he says, arises from the sternum and clavicle (my dissections, as noticed above, do not bear out the latter part of the statement; but as he did not separate the clavicular deltoid from the sternal pectoral, he looked on the origin of the latter as part of that of the former), the second part is clavicular, and the third also from the clavicle. In their Plates of *Pteropus*, CUVIER

and LAURILLARD figure this muscle as the petit pectoral; HUMPHRY regards it as a part of the great pectoral, and corrects CUVIER'S error of assigning to it a costal origin. The fact of this muscle and the pars sternalis receiving their nervous supply from the anterior thoracic nerve, a branch of the external cord of the brachial plexus, settles the question of its morphological nature.

Pectoralis minor is absent in every species.

Pectoralis quartus in all is a distinct, well-developed muscle, largest proportionally in *Noctulina*, smallest in the Pipistrelle, and very small in *Scotophilus hesperus*. In general it arises from the superficial fascia of the abdomen opposite the level of the lower margin of the thorax, at the anterior termination of the upper false ribs; in no case did its origin stretch as a separate structure to the pubis, and it invariably was distinctly superficial to the rectus abdominis; and even when I detached artificially a slip of the fascia to make a factitious origin, it lay over and not alongside, or in any sense in common with the rectus, as Professor HUMPHRY describes. In *Cephalotes* its origin is from the middle line of the abdomen at its middle point, and its fleshy fibres overlie those of the rectus, crossing them at a small angle; in this species it passes underneath the pars sternalis of the great pectoral to be inserted into the uppermost point of the pectoral crest of the humerus, immediately inferior to the insertion of the pars clavicularis. In all the species except *Plecotus* it was perfectly detached from the great pectoral, and in that species it was merely connected with it at its insertion. In every other instance the muscle ended in a long tendon, by which it is inserted into the summit of the pectoral crest. In *Pteropus edulis* its origin corresponds to the linea alba, an inch below the ensiform cartilage, and extending down for one fourth of this line.

Its origin is always superficial, and below the great pectoral; but owing to the greater verticality of its fibres it soon sinks under cover of that muscle. In *Pteropus* and its allies the insertion is, as described by Professor HUMPHRY, into the point below the pars clavicularis. In *Vampyrops vittatus* and *Artibeus jamaicensis* it is also below, but not quite in contact with the other muscle. In *Vespertilio* and *Scotophilus* it is behind the pars clavicularis. It is thin and inserted higher up in *Megaderma*. In *Eleutherura* it arises from the middle line of the upper third of the abdomen, also superficial to and separate from the rectus, and it extends even over the ensiform cartilage. This muscle is regarded by CUVIER and LAURILLARD as the portion ventrale of the great pectoral, and by Professor HUMPHRY is considered as probably the representative of the pectoralis minor (*loc. cit.* p. 301). It is, however, a muscle of a different nature, one whose synonyms are numerous, and which has been recognized as a distinct muscle by Professor HUMPHRY in the Orycterope and Seal, under the name of *brachio-lateralis**. In Man it often

* The names given to this muscle in different animals are legion. It has been called humero-abdominalis (KLEIN), abdomino-humeralis (DUGÈS), costo-humeralis (HUXLEY), chondro-epitrochlear (DUVERNOY), brachio-abdominalis (ZENKER), brachio-lateralis (HUMPHRY), portio-abdominalis pectoralis majoris (ECKER). Pectoralis quartus, the name given to it above, was settled on by Professor HAUGHTON and myself as the name by which we should call it.

coexists* with the lesser pectoral as an anomaly; and in one of its conditions it is known as the chondro-epitrochlearis. That it is not pectoralis minor is shown by this fact, and also by the fact that it is supplied by the anterior thoracic nerve from the outer cord of the brachial plexus, not by the middle, which should supply it if it were lesser pectoral.

CUVIER and MECKEL describe a muscle passing in the Bat from the three upper ribs to the coracoid process with a broad tendon of insertion; this they call the pectoralis minor. I have not seen the least trace of a muscle like this in the whole course of my dissections, nor has HUMPHRY met with it in his *Pteropus*.

A strong costo-coracoid membrane underlies the pars clavicularis of the great pectoral and covers the subclavius; this is weakest in *Rhinolophus diadema* and *Cephalotes*, strongest in *Macroglossus*. The subclavius (Plate XIII. fig. 13, *a*) beneath it in all passes from the first rib to the clavicle, and has no connexion with any other bones; its origin is tendinous in *Megaderma* and *Plecotus*. This tendon is long in the Pipistrelle; its costal attachment is fleshy and tendinous in *Pteropus*, and is fleshy and from a large extent of the first rib in *Pteropus*, *Cephalotes*, and *Macroglossus*. Its insertion is into the outer half of the under surface of the clavicle, or the outer seven eighths as in *Megaderma*, or two thirds as in *Artibeus*. The muscle is proportionally smallest in *Noctulina*. Its non-extension is interesting, as this is the homologue of the levator humeri of the bird, whose extension to the humerus is of such importance in avian flight, thus indicating the difference between the mechanism of flight in the two series.

Serratus magnus is a double muscle in all the Bats, and consists of an inferior and a superior part; the former arises from a varying number of ribs below the first, eight in *Plecotus*, *Synotus*, *Vespertilio*, and *Noctulina*, with two slips from the second rib in *Vespertilio murinus*, *Vesperugo pipistrellus*, and *Noctulina*, with a single wide slip in *Plecotus* and *Synotus*. In *Macroglossus* it is attached to nine ribs, with only one slip from the second; in *Artibeus* and *Vampyrops* it is attached also to nine; in *Pteropus medius* and *Edwardsii* to eight, or ten, as in *P. edulis*; in *Megaderma* to nine. MECKEL describes it as arising from the ribs, except the two last; it is inserted into the inferior and external border of the scapula between the teres major and the subscapularis, sometimes rising nearly halfway along the axillary margin of the scapula, as in *Megaderma*. In *Vampyrops* it has an attachment higher up to the posterior border, and a tendinous sling stretches from this to the main insertion at the lower angle.

Serratus magnus superior arises from the first rib in the Rhinolophidæ, Phyllostomidæ, as well as in *Vesperugo* and *Scotophilus*. In *Noctulina* it arises from the upper three ribs behind the upper border of the serratus inferior; in *Pteropus* it has a second tooth from the second rib; its origin is under the scaleni, and is inserted into the vertebral edge of the scapula at its upper angle under cover of the insertion of the levator anguli scapulæ, from which it is perfectly separate in all the Cheiroptera, even in *Megaderma*, in which the serratus magnus superior arises from the first rib, and from the transverse process of the last cervical vertebræ.

* I figured and described this muscle in *Cebus capucinus*, Proc. Nat. Hist. Soc. Dubl. 1866, pl. 1.

Serratus anticus arises (Plate XV. fig. 1, *u*) from the sternum beneath the pars sternalis of the great pectoral, and overlying the prolonged rectus abdominis is inserted into the first rib below the origin of the subclavius; its sternal origins are as usual tendinous, and its insertion fleshy. In *Vesperugo* it extended as far down as the attachment of the fifth rib-cartilage to the sternum, in *Noctulina* only to the second sterno-chondral articulation; in *Artibeus* it extended to the third: in *Vampyrops* it was divided into two parts, one of which was attached to the sternum opposite the third rib-cartilage and to the second rib-cartilage; the other passed from the sternum to the first rib. In *Pteropus* it is very weak, and extended as far down as the third sterno-chondral joint; it is strong, fleshy, and thick in *Cephalotes* and *Eleutherura.*

The intercostals, infracostals, and transversus thoracis anterior presented no noteworthy features.

Muscles of the Back.

The nuchal hollow in all the specimens was filled up by a fatty mass, which in my large *Pt. edulis* was an inch in thickness in the middle; this lay below the occipito-pollicalis, which we have before described as probably the occipital trapezius; on clearing this out, no distinct trace of a ligamentum nuchæ exists.

The second part of the trapezius muscle, or the trapezius dorsalis is large and with a very thick rounded upper border. In *Artibeus* and *Vampyrops* a semidetached upper slip passed from the two lowermost cervical spines to the outer fifth of the clavicle; this is weak, and is the only trace of the cervical trapezius in the entire order. The proper dorsal trapezius is a single muscle in *Pteropus*, *Macroglossus*, *Cephalotes*, *Plecotus*, *Vesperugo*, and *Eleutherura*; it arises from the spines of all the dorsal vertebræ but the two lowest in *Macroglossus*, all but the lowest five in *Cephalotes*, from all in *Plecotus*, not so far down in the Pipistrelle and *Scotophilus*, but I could not ascertain by how many they fell short; it is inserted into the upper margin of the spine of the scapula and acromion process. In *Myotus murinus* it is attached to eleven dorsal spines, as described by CUVIER, MECKEL, and KOLENATI. In *Pteropus* the fibres extend to the outer fifth of the clavicle; in the Pipistrelle there is also a clavicular fascicle. In *Noctulina* the muscle is double, the superior dorsal trapezius arising from the spines of the vertebræ in the uppermost third of the dorsal region; and these fibres run transversely across to the scapular spine and acromion, making a quadrilateral muscle. The inferior trapezius springs from the spines of the vertebræ in the middle third of the dorsal region; its fibres ascend, and are inserted into the posterior margin of the scapula at the base of the spine; for a short distance before its insertion the muscle becomes tendinous. In *Vampyrops*, *Artibeus*, *Megaderma*, and *Rhinolophus* the trapezius is also cleft (Plate XIII. fig. 9, *f*), and the widest interval exists in the last two of these genera. In *Megaderma* the superior trapezius arises from the three uppermost dorsal spines, the inferior from the lowest four, the intervening space being only occupied by a very thin cellular expansion, through which the fibres of the rhomboid were visible; the inferior portion was inserted by a long tendon into the superior angle of

the scapula; the superior portion sends a few of its fibres to the outer eighth of the clavicle. In *Rhinolophus diadema* and *speoris* the arrangement is the same. In the Vampyres the muscle is divided into an upper and lower part also; the upper from the four superior dorsal spines to the acromion, the lower begins two or three vertebræ below, and extends down to the second from the last dorsal vertebra: this portion is connected to the latissimus dorsi at its origin, and reminds one of the inferior trapezius in the bird. The lowest fibres of this muscle are continued into the posterior marginal fibres of the acromial deltoid, a tendinous inscription marking the line of fusion. An approach to this doubleness exists in the Pipistrelle, in which the central part of a single trapezius is intersected by a tendinous line. In the *Megaderma* I traced the principal part of the spinal accessory distinctly into this muscle, the upper branch of it going, as before mentioned, to the occipito-pollicalis. In all the upper border of trapezius is twice or thrice as thick as the lower.

Rhomboideus (Plate XV. fig. 2, *j*) is a single undivided muscle in all, never prolonged up to the occiput; its fibres do not rise higher than the spine of the first dorsal vertebra, and they extend to the fourth in the Pipistrelle and *Plecotus*, to five in *Myotus*, *Cephalotes*, *Eleutherura*, and *Megaderma*. It is strongest in the *Pteropi*, next in the Phyllostomidæ. MECKEL states that it arises from the lowest cervical vertebræ, but this I have not found in any species; its insertion is into the hinder margin of the post-scapula, and in *Megaderma* it extends to the hinder edge of the meso-scapula.

Serratus posticus superior in all is very thin, so thin, indeed, as to be scarcely demonstrable; it is only attached to two ribs in *Myotus*, *Synotus*, and *Plecotus*, to three ribs in *Vampyrops* and *Artibeus*, to the four uppermost, except the first, in *Cephalotes*. MECKEL says the superior is much stronger than the inferior; but I found very little difficulty in tracing both in many of the species, and in *Megaderma* the lower is the stronger.

Serratus posticus inferior, still thinner, is only attached to two ribs in the Pipistrelle, to the same number in *Vampyrops*, to five in *Cephalotes*, to three in *Megaderma*, in which it is proportionally strongest.

Splenius (Plate XIII. fig. 9, *a*, & Plate XV. fig. 2, *d*), a single large muscle arising from the five lowermost cervical and one dorsal spines; in all it is undivided and attached to the occiput, as well as to the two or three upper cervical transverse processes. In *Pteropus* it is purely occipital, and has a tendinous insertion.

In *Megaderma lyra* this muscle covers over a rhombo-atloid slip, which passes from the transverse process of the atlas to the spine of the first dorsal vertebra. I did not see this in any other species. This muscle occurs elsewhere as an anomaly in Man.

Complexus in the *Vampyrops* is a thick muscular mass, including in it the complexus proper, trachelo-mastoid, and the biventer cervicis; it presents no intersections. In *Megaderma* and *Pteropus* the biventer is separate, and is strong and straight with a distinct linear transverse inscription; it arises from the spine and transverse processes of the upper dorsal vertebræ (one or two), and is inserted into the occiput. The com-

plexus proper is attached below to the lower two or three cervical transverse processes. MECKEL says these muscles have no inscriptions in the Bats.

Latissimus dorsi in *Macroglossus minimus* and *Cephalotes* arises from the spines of the four lower dorsal vertebræ; in *Pteropus medius* and *Edwardsii* from three; in *Pt. edulis* from four; in *Eleutherura* from the four lower dorsal and two upper lumbar spines; from three dorsal and two lumbar in *Megaderma*. In none has it any costal attachment; the fibres run upwards, outwards, and forwards, to be inserted into the inner bicipital edge of the humerus above the teres major, and directly below the inner tuberosity. CUVIER gives as its origin the two lowest dorsal spines, and mentions its being connected to the trapezius (*loc. cit.* i. p. 276); this is denied by MECKEL (*loc. cit.* p. 267); but nevertheless, as mentioned before (see trapezius), it is true in one genus. In *Noctulina* it occupies the lowest third of the dorsal region, springing from four dorsal spines. In all the species a bursa separates its tendon from that of the teres major. In the Vampyres it has an additional lumbar vertebra in its origin, and gets a slip from the iliac crest; in the Pipistrelle its lumbar origin is very scanty, and only attached to two vertebræ. CUVIER says its tendon is joined to that of the teres major, which arrangement did not exist in a single specimen dissected by me.

The erectores spinæ are very feeble, weaker than in any other group of mammals according to MECKEL. The sacro-lumbalis is only attached to the nine lower ribs in *Megaderma*. In the smaller species these muscles justify CUVIER's description, by existing as a few tendinous fibres near the spine. Extensores caudæ in the Noctule are long, and pass from the sacrum as usual; there is no separable multifidus spinæ as MECKEL describes. The obliquus superior capitis is very small in *Megaderma*, and lies parallel and internal to the rectus capitis lateralis; the obliquus inferior is equally large, and the rectus capitis posticus major is wide and triangular, with a broad insertion; the rectus posticus minor is small, short, and square. In *Plecotus* the occipitalis major nerve is very large, and sends filaments to ramify on the back of the ear.

The levator anguli scapulæ in all is a separate moderately large muscle; in the Vampyre it consists of two slips one over another; it lies on a plane superficial to the serratus and above the rhomboideus; its origin is from the sixth and seventh cervical transverse processes, and its insertion is into the posterior border of the scapula above the spine. It is single, but with the same attachments in the *Plecotus*, Pipistrelle, and Noctule. In *Cephalotes* it also is attached to the two lowest cervical vertebræ, to the posterior border of the prescapula; and the same is the arrangement in the *Eleutherura* and *Pteropi*. In *Megaderma* it overlies the slip of the serratus magnus superior from the seventh cervical transverse process, from which it is separated by the posterior muscular branch of the brachial plexus passing back to supply the rhomboid.

Levator claviculæ (omo-atlanticus, omo-trachélien, acromio-trachélien, trachelo-acromial, acromio-basilar, cervico-humeral of divers authors) I found in all but *Plecotus*; it arises above the levator anguli scapulæ from the fourth and fifth cervical transverse processes, in *Pteropus* from the second and third (HUMPHRY, p. 304), and is inserted

into the clavicle at its outer fourth, behind the cervical trapezius when that muscle exists; in the Pipistrelle it arises from the fourth alone; in *Pteropus* its fibres run to the outer point of trisection of the clavicle. It is very strong in *Cephalotes*, and sends some fibres to the acromion.

Muscles of the Upper Extremity.

The deltoid is divided into three parts in general, which look like perfectly separate muscles; the acromial deltoid (Plate XIII. figs. 9, *c*, 10, *a*) is very distinct, arising from the acromion process of the scapula, and inserted into the upper and outer part of the humerus on the outer side of the pectoral ridge. In *Macroglossus* and *Pteropus* it extends below the pectoral muscle (the same length in *Pt. Edwardsii*, twice as far down in *Pt. edulis*, Humphry). I could not find in any of the species of *Pteropus*, *Eleutherura*, *Cephalotes*, or *Macroglossus* any of the posterior fibres running into the triceps; they are closely applied together, and without careful dissection cannot be separated. In *Plecotus* this muscle is solid and thick, and its insertion is high up; the opposite extreme in the way of length is in *Eleutherura*, in which the muscle extends for one sixth of the humerus below the inferior border of the insertion of the great pectoral. In *Vampyrops* the fibres run from the acromion in a radiating manner, the upper being short and nearly transverse, the lowest being long and oblique. In *Megaderma* its origin extends behind the acromion from the meso-scapula, and its fibres take the same course as in *Vampyrops*; thus its fibres have the same relation to the clavicular deltoid that the scapular deltoid has to it.

The clavicular deltoid is in general, as MECKEL describes, inseparable from the great pectoral, and is not absent as CUVIER supposed; it is always separate from the acromial portion: the muscle is partly separated from the pars sternalis of the pectoral in *Eleutherura*, completely separated in *Megaderma* and *Pteropus edulis*, arising from the outer fifth of the clavicle (outer half in *Pt. edulis*); it is inserted over the pectoralis major, and the borders of the muscles are superficially marked out from each other by a vein (the cephalic). In *Pteropus Edwardsii*, HUMPHRY found the deltoid attached to the outer half of the clavicle, internal to the insertion of the trapezius; he also found it blended with the pectoralis major at its insertion (*loc. cit.* p. 305). It is always with the pars sternalis of the pectoral that the clavicular deltoid is fused, not with the pars clavicularis, which lies on a plane deeper.

The scapular deltoid (Plate XIII. figs. 9, *g*, & 10, *d*) is nearly inseparable from the acromial in *Rhinolophus diadema*, at least the contiguous fibres are nearly parallel and closely applied to each other. In general this muscle arises from the margins of the infraspinous fossa, over the infraspinatus muscle, from which it is separated by a thin layer of fascia. In *Macroglossus* it is attached to the posterior half of the lower margin of the scapular spine, as well as to the posterior margin of the postscapula. In *Eleutherura* its fibres are very transverse, chiefly from the hinder margin, and on the same plane with those of the teres major. In the Pipistrelle its outer and upper fibres are

nearly parallel to the posterior border of the acromial deltoid, showing its deltoid nature In *Noctulina altivolans* none of its fibres are meso-scapular; they all arise from the posterior margin. In *Vampyrops* its origin is also posterior. The insertion in all is into the external side of the humerus, below the external tuberosity and under cover of the acromial portion; the insertion is single in *Pteropus* and its allies, except *Pt. edulis*, double in *Vampyrops* and *Artibeus* and *Pt. edulis*; in the two former the two slips of insertion are a considerable distance apart. In *Plecotus, Vespertilio, Vesperugo*, and *Scotophilus* the insertion is single also. In *Megaderma* a few fibres of the trapezius are continued into its upper border.

In *Megaderma* this muscle is very deltoidean in appearance in the direction of its fibres; it is least so in *Cephalotes*, in which, as in *Noctulina*, no fibres arise from the spine of the scapula.

Professor HUMPHRY considers this muscle as teres minor, CUVIER more properly recognized its deltoidean nature, MECKEL confounded it with the infraspinatus, which he describes as very thick. That it is the scapular deltoid is plain from its position overlying the infraspinatus and its fascial relation, lying between two laminæ of the infraspinous fascia, and from its coexistence with a beautiful little teres minor; indeed the only feature not deltoidean about it is its transverse direction, a condition which gives it great power in rotating and retracting the humerus.

Supraspinatus (Plate XIII. fig. 11, *c*) is a moderately strong muscle, penniform in structure, and placed under a strong fascia, whose upper border is thickened into a very strong suprascapular ligament; it is larger than the infraspinatus in *Pteropus*, smaller in *Cephalotes* and *Megaderma*; the difference between the two, however, is very slight. MECKEL says the infraspinatus is much the larger, because he included the last muscle together with the infraspinatus proper under this head; its tendon crosses the upper part of the joint, and is in contact with the synovial membrane in *Macroglossus*, the capsule being deficient under it.

Infraspinatus (Plate XIII. fig. 12, *h*) is proportionally largest in *Rhinolophus diadema* and *speoris*, being more than twice as large as the supraspinatus. In no species did I find any difficulty in separating it from the supraspinatus, although MECKEL says they are scarcely separable; it is separated from the deltoid by a deep layer of fascia, and a strong spino-glenoid ligament lies between it and the supraspinatus; its tendon is closely applied to the capsule of the shoulder, and is inserted into the greater tuberosity below the last. In *Megaderma* this muscle is elongated and penniform, and overlapped by the teres major.

Teres minor is a beautiful little muscle, whose existence has not been noticed by any anatomist; it lies under cover of the infraspinatus; in *Pteropus edulis* it was half an inch long, and its insertion was a quarter of an inch broad (Plate XIII. fig. 12, *i*); it arises from the axillary costa, as usual, for about a line or a line and a half; its tendon of origin crosses over the triceps longus, becomes fleshy, and is inserted below the infraspinatus into the greater tuberosity; and its insertion is easily distinguished from that of the last

named muscle, as it is fleshy, while that of the infraspinatus is tendinous. It is proportionally largest in *Plecotus* and *Noctulina*, very small, flat, and thin in *Megaderma*; it has a fleshy origin in *Cephalotes*; in *Cynonycteris* it is very short and thick, while it is absent in the Pipistrelle, *Vespertilio murinus*, and *Scotophilus*. MECKEL says this muscle is absent (*loc. cit.* p. 276); I could not determine the nervous supply of this muscle in any of the species.

Teres major is a large muscle and displays nothing remarkable; its tendon is inserted further from the latissimus dorsi than in most animals, being completely below it. It is developed in about equal proportion in all, being about three fourths the size of the combined supra- and infraspinati.

Subscapularis (Plate XIII. fig. 13, *b*) is a remarkable muscle, as probably the largest subscapulars in the animal kingdom are possessed by Bats; the thickness of this muscle is enormous, and it occupies the entire subscapular fossa; it has a few tendinous septa in it, and its tendon is not in contact with the synovial membrane as Professor HUMPHRY has noticed. A separate subscapulo-humeral slip exists in all the larger Pteropine and Phyllostomine Bats (Plate XIII. fig. 13, *c*).

Coraco-brachialis is a small muscle in all; but Mr. WOOD is in error in supposing it to be the true coraco-brachialis brevis (Journal of Anat. and Phys. vol. i. p. 52, 1866). If we limit that name to the muscle whose insertion is above, or connected to the insertion of the teres major and latissimus dorsi, then in none of the Bats examined is there a short coraco-brachialis. It arises from the coracoid process beneath the coracoid head of the biceps; its insertion is into the inner side of the humerus, below the latissimus and teres tendons. In *Plecotus* it is inserted into the upper fifth of the bone; in *Myotus murinus* its insertion is opposite to the middle of that of the deltoideus acromialis. In *Cynonycteris* it is, as in *Cephalotes*, attached to the upper fourth of the humerus. In *Artibeus* it is still shorter, but still plainly not a coraco-brachialis brevis. In none is a long form of the muscle present. In *Synotus barbastellus*, *Vesperugo Kuhlii*, and the Pipistrelle it is the same as in the *V. murinus*. In *Vampyrops* it is slender and much larger, passing much further down the humerus to its insertion, which is opposite the upper part of the middle third of the bone. In *Macroglossus* it is closely connected to the biceps at its origin, and its insertion is into a little more than the upper third of the humerus; it is partly divisible into two parts in this genus, but they both partake of the characters of the coraco-brachialis medius. In no species, even of *Pteropus*, did I find it possessing the connecting fibres to the brachialis anticus described in *Pteropus Edwardsii* by Professor HUMPHRY; it is very short in *Noctulina*. CUVIER says it is absent in the Bats (Leçons Orales, i. p. 277); but MECKEL found it and describes it (Comp. Anat. vol. vi. p. 281). HUMPHRY found it bipartite in *Pteropus*, one part coming from the biceps short head, the other from the coracoid process; these are separated by a plane of cellular tissue as in *Macroglossus*. In *Megaderma* the muscle is single, beneath the coracoid head of the biceps, and it lies on the external cutaneous nerve which lies between it and the bone; the insertion is into the second and third sixths of the humerus.

In *Rhinolophus diadema* the coraco-brachialis is shorter than in any other species. In *Eleutherura* and *Epomophorus* this muscle has its insertion into a tendinous sling, such as that which Professor HENLE figures as the normal method of its insertion in Man (Muskellehre, fig. 86), and it occupies the middle third of the humerus; in this species likewise the origin is separated from the origin of the coraco-cutaneus by the external cutaneous nerve. In *Pteropus edulis* this muscle extends halfway down the arm, is pierced by the external cutaneous, and from its posterior side it gives an origin to the inner head of the triceps.

Biceps flexor cubiti (Plate XIII. fig. 13, *f*) always consists of two heads, which are very separate, at their origins at least; the internal of these arises from the extremity of the coracoid process, the external from the margin of the glenoid cavity at the foot of that process on its outer side: the former of these soon becomes fleshy, forming a wide thick upper fleshy part of the muscle; the latter runs from its origin over the upper part of the humerus as a thick hard strap, and becomes fleshy on a lower level than the former. Professor HUMPHRY remarks that neither can be called truly glenoidal; but the same author has elsewhere remarked that the long head usually springs from that part of the glenoid cavity which belongs to the coracoid process. In *Cephalotes Pallasii* the coracoid tendon passes further than usual before becoming fleshy, and lies in front of the coraco-brachialis; the two bellies in this species likewise are perfectly distinct for their whole extent, and they are inserted into the radius, the coracoid being in front of the other part: in this species the tendon of the long head extends into the shoulder-joint; the belly in connexion with this head is three times the size of the coracoid belly. In *Plecotus* the two parts unite high up, and form a very short and very thick belly, which is very protuberant in the arm under the insertion of the pectoral muscle; this is only one fourth the length of the arm, and its tendon of insertion is twice as long below: in the Pipistrelle there is a similar long tendon. In *Vampyrops* the coracoid head is fleshy above, and becomes sooner tendinous than the glenoid; the upper tendon of the latter is very thick where it passes over the shoulder-joint. In *Macroglossus* the coracoid biceps is one third the size of the glenoid; they are nearly equal in *Vampyrops*; and in *Artibeus* they are similar, but proportionally larger than in the last named.

In *Noctulina* the coracoid is one half the size of the glenoid, and the tendon of insertion is very long. The biceps in all is inserted into the ulnar or inner side of the radius below its tubercle, a bursa lying under the tendon; this tendon is single in *Plecotus, Synotus, Noctulina, Vespertilio, Vesperugo*, and *Scotophilus*. In no case did I find any humeral head, or the slightest trace of any fibres from the humerus into the biceps in any of the nineteen specimens dissected. This is remarkable, as MECKEL has described the biceps in the Bat as arising from the coracoid and the humerus, which soon unite (Anat. Comp. vol. vi. p. 290); and Professor HUMPHRY in the female *Pteropus* found some fibres of the brachialis anticus going into the biceps. In *Megaderma lyra* the coracoid head is one third of the glenoid. In *Rhinolophus diadema* the two are separate for their whole length: in the coracoid the belly is one fourth of the arm, and the tendon

three fourths; in the glenoid the tendon is half the length of the arm and the belly half. Except in *Eleutherura* and *Cephalotes* the bursa beneath the long tendon does not open into the shoulder-joint. Professor HUMPHRY describes it correctly in *Pteropus* as lying in a separate bursal canal and being separate to its insertion. Professor AEBY says that in the common Bat the two heads are perfectly fused together (SIEBOLD & KÖLLIKER'S Zeitschrift, x. p. 45). According to this author the biceps is to the brachialis anticus in weight as 30·73 : 1·40.

The brachialis anticus is a very small muscle, so small in *Macroglossus* as to be scarcely detectable; it arises from the external side of the humerus, in front of and above the musculo-spiral nerve and external to the biceps; it passes posterior to that muscle to be inserted into the ulna. A bursa separates its tendon from that of the biceps. MECKEL describes this muscle as long and slender. In *Plecotus* and the others of the Vespertilionidæ it arises from the upper point of trisection of the humerus, and seems like a single thread of muscular fibre. Professor HUMPHRY speaks of it as arising from the *inner* side of the humerus just beneath the insertion of the coraco-brachialis, an arrangement which I did not see in any of my specimens of Pteropine Bats; in them its origin is anterior, and in *P. edulis*, though inclining slightly to the inner side, yet still on a plane, is inclined to the coraco-brachialis. This muscle is largest proportionally in the *Eleutherura marginata*; it is also large in *Cephalotes*, and arises from the front of the humerus, commencing below the pectoral ridge but not near the coraco-brachialis; its insertion is behind the long head of the biceps. Professor HUMPHRY found in the female *Pteropus* a band of this muscle going into the biceps, which I did not see in any of my specimens. In *Cynonycteris* it was exceedingly feeble.

Triceps longus in *Plecotus* arises as usual from the tricipital subglenoid ridge; it has a single thick upper belly and a long tendon, which is separate from the tendon of the rest of the muscle until near its insertion; it is overlain by a thin dorsi-epitrochlear expansion, more areolar than muscular in structure, but which comes off from the tendon of the latissimus dorsi. In the other Vespertilionine Bats the long head is double, composed of two perfectly distinct muscles, one of which arises a little above the other. In *Vampyrops* there are also two scapular heads, which very soon coalesce. In *Artibeus jamaicensis* there are two similar long heads, but they do not unite so high up.

In *Macroglossus* the origin is single, wide, with no trace of a dorsi epitrochlearis, and coalesces with the humeral heads before its insertion; it is similar in *Cephalotes*, but in *Megaderma* it is distinctly double, the external being large with a tendinous origin, the internal being tendinous and fleshy; they are quite separate to the lowest fifth; no trace of a dorsi epitrochlear exists in this species. MECKEL says that the triceps in the Bat has three heads of the same length; one of these is scapular, two are humeral, arising from the upper part of that bone, while a fourth head arises from the back of the humerus lower down. In *Pteropus* Professor HUMPHRY describes finding some fibres from the acromion deltoid passing into this muscle; but this arrangement I have failed to find in any species, although in *Eleutherura* and *Pteropus* they are closely applied.

Professor HUMPHRY also found some fibres passing into the triceps from the posterior surface of the tendon of the coraco-brachialis (*loc. cit.* p. 305); this likewise I have not found, except in the three species of *Pteropus*. In *Eleutherura* the triceps has two scapular heads, of which the external is three times larger than the internal. The long head is partly double at its origin in *Pteropus edulis*.

As already mentioned, the only traces of the dorsi epitrochlearis exist in the Vespertilionidæ; in all of these it is extremely weak, but it is largest proportionally in the Pipistrelle.

The humeral head of the triceps is single in *Megaderma* and is external; indeed Professor AEBY regards it in all Bats as single and with germs of two lateral heads (SIEBOLD & KÖLLIKER's Zeitschrift, x. p. 41). In *Rhinolophus diadema* there is a single long external humeral head and a double scapular origin, and no fibres for the lower part of the back of the humerus. In *Cephalotes* there is a large external humeral origin ascending to the head of the humerus, and a small internal slip separated by the musculo-spiral nerve. In *Vampyrops* the two parts are separate, but soon coalesce. In *Plecotus* the humeral triceps is excessively weak and single; it is the same in the Pipistrelle, a little stronger in *Vespertilio murinus* and the Noctule; in all the fibres pass down the humerus, and are inserted into the extremity of the ulna. In all the species a detached sesamoid bone exists in the tendon above the extremity of the ulna, exactly resembling a patella; this has been long known, having been described by GRATIOLET and GEOFFROY ST. HILAIRE ("Sur l'existence d'un osteïde dans le tendon de l'extenseur de l'avant-bras," Nouvelle Bulletin Scient. Philomath. p. 158, 1826).

The musculo-spiral nerve winds round the humerus at its lower fourth, lower in *Megaderma* than in any other species; the ulnar nerve passes along the brachial artery, then passes behind the inner condyle, sending a filament to the little finger, one to the dactylopatagium latus, and two to the back of the forearm; this arrangement was easily traceable in *Noctulina*.

The proportion between the flexors and extensors has been studied by Professor AEBY of Basel; he finds the triceps to be 25·65 per cent., the biceps and brachialis 32·13 (in Table xvi. p. 86 he has misplaced these numbers; but this is as they should be from his data, p. 85).

The muscles of the forearm are singularly beautiful and well deserve a careful study; the flexors are inferior in strength to the extensors in the forearm; but this is exactly made up by the preponderance of short flexors in the manus, which render these groups of muscle nearly equal; the motions which they produce are simple flexion and extension in a single plane: rotation of any kind is not permissible in the elbow- or wrist-joints; as the latter is only a single forearm bone, its possibilities of motions are thereby simplified. The usual four groups of muscles, supinator, pronator, flexor, extensor, are represented in general as follows:—

Pronator radii teres (Plate XIV. figs. 1, *b*, & 5, *d*) is said by CUVIER to be absent, as well as the pronator quadratus and the supinators (Leçons, i. p. 298). MECKEL admits

the presence of this muscle, but denies the existence of a supinator longus; this muscle arises from the inner condyle and is inserted into the upper fourth of the anterior and internal aspect of the radius; its origin is tendinous, the main body and insertion are fleshy; this is its arrangement in *Megaderma*, *Rhinolophus*, *Pteropus*, and *Macroglossus*: it occupies only one fifth in the *Vespertilio murinus*; this accords with MECKEL's description: it covers one third fully in *Vampyrops*, *Pteropus Edwardsii*, *Cephalotes*, *Plecotus*, *Synotus*, and *Noctulina*, about two fifths in the Pipistrelle. In all it overlies the median nerve which supplies it; in none has it an ulnar or radial origin. The insertion is into an oblique ridge on the radius. This muscle can only act as a feeble flexor of the elbow.

Pronator quadratus is absent in all.

Supinator radii longus (Plate XIV. fig. 5, *c*), whose existence was first demonstrated by HUMPHRY, exists in all except the *Noctulina* and Pipistrelle. It arises above all the other ecto-condylar muscles, and separates from them immediately below the musculo-spiral groove, and is inserted either into the external and anterior surface of the radius immediately opposite those of the last-described muscle, or else into the integument of the front of the forearm. In *Plecotus* the insertion is into the upper fourth of the radius; in *Cephalotes*, in which it arises higher than in any other species, the insertion is into the upper point of trisection of the forearm; the origin is higher in *Macroglossus* than in *Vampyrops*, but lower than in the last. In *Megaderma* is a distinct fine band, which is inserted into the uppermost part of quadrisection of the radius. In *Eleutherura* it has no bony attachment. This muscle can only act as a simple flexor, as AEBY has pointed out (*l. c.* p. 46); it is supplied by a twig from the large musculo-spiral nerve which lies in front of it. The external cutaneous nerve crosses it, having passed over or under (never through, except in *P. edulis*) the coraco-brachialis muscle and behind the biceps; it is then distributed to the propatagium.

Supinator brevis is a thick simple muscle, in all arising from the outer condyle and inserted into the upper fifth of the radius; it is beneath and connected to the other extensor muscles; its fibres run vertically downwards and a little forwards to be inserted above those of the supinator longus, nearly opposite to those of the pronator teres; no nerve pierces this muscle, as there is no posterior interosseal branch from the musculo-spiral nerve in any Bat which I have examined.

From the external condyle I have seen a few fibres arising in *Vampyrops*, and passing into the skin of the plagiopatagium; these are very short, and resemble the humero-cutaneus described before. KOLENATI, in describing the forearm-muscles, says of them, "schicken von ihren Köpfen Muskelfasern zu den Dactylopatagien;" possibly it may be some band like these that he refers to, but these go to the plagiopatagium. No other author alludes to them; I found them also in *Plecotus*, in which they extended for the upper sixth of the forearm.

Flexor carpi radialis (Plate XIV. figs. 1, *c*, & 3, *a*) is the second most anterior muscle from the inner condyle; its origin is conjoint with the pronator, but it soon becomes separate, and ends in a tendon which runs to the pollical side of the wrist. In *Macroglossus* its insertion is into the scapho-lunar bone, into the trapezium, and into the base

of the second metacarpal; of these three the trapezial slips come off first from the outer edge of the tendon, then the remaining part bifurcates; the tendon for the scapho-lunar bone is the largest. In *Vampyrops* its insertion is purely into the trapezium; in *Plecotus* it is purely into the second metacarpal; in the Pipistrelle it seems lost on the carpus; it is absent in *Noctulina*; attached by a single insertion in *Pteropus Edwardsii* to the ulnar side of base of the metacarpal of the index, according to Professor HUMPHRY; it has a single tendon to the scapho-lunar bone in *Cephalotes*, to the base of the index metacarpal in *Megaderma*. In *Artibeus* it is single and simple.

Flexor carpi ulnaris (Plate XIV. figs. 1, *e*, & 3, *k*) arises principally from the subolecranon part of the ulna, but generally receives a small slip from the inner condyle; these two heads present the usual relation to the ulnar nerve which separate them. CUVIER says this muscle arises from the common fleshy mass at the condyle, a description which will be seen to be erroneous in almost every species. In *Noctulina* this muscle, however, has no olecranon origin; it continues fleshy longer than most of the other flexors, and is inserted in *Noctulina* into the transverse process of the os magnum; the ulnar nerve is internal to its origin, then gets under it and is external for its whole length. In *Macroglossus minimus* its insertion is threefold, into the transverse process of the os magnum, to the base of the fourth and fifth metacarpals, and by a narrow thread which detached itself high up into the origin of the abductor minimi digiti. CUVIER describes it as inserted into the first phalanx of the fifth digit; I did not find this mode of insertion in any specimen. In *Pteropus Edwardsii* HUMPHRY only found a single tendon inserted into the distal margin of the transverse process of the os magnum opposite the interval between the third and fourth metacarpals; in *Pt. edulis* it was much the same, and the muscle was large and fleshy. In *Cephalotes* it has an origin from the supraolecranon sesamoid bone, and is inserted into the fourth and fifth metacarpals and into the abductor minimi digiti. *Plecotus* has this muscle also attached to the fifth metacarpal. In *Vampyrops* and *Megaderma* it arises solely from the olecranon; in *Artibeus* it is also ulnar; in *Cynonycteris* its origin is condylo-ulnar; in *Vampyrops* it has a wide, apparently double tendon of insertion into the os magnum and the fifth metacarpal; in *Megaderma* it has a small round ossicle in its tendon in the palm attached to the os magnum and to the bases of the fourth and fifth metacarpal bones; from this ossicle the fourth and fifth finger interossei arise.

Professor HUMPHRY describes two flexor muscles for the digits; one of these he calls flexor sublimis digitorum, the other flexor profundus. A careful study of these two muscles in the whole series does not bear out the first part of this recognition: the so-called superficial flexor is really a palmaris, as will be seen from the nature of its insertion; the deep flexor is a combined flexor profundus digitorum and flexor pollicis.

In *Vampyrops* the palmaris arises from the internal condyle and from the upper part of the radius; it soon becomes tendinous, and passing superficial to the other parts at the wrist, it is inserted, by two flat slips, into the metacarpal bone of the pollex, one at either side; a third equally flat band is attached to the metacarpal bone of the index, and a

fourth to that of the middle finger; none of these extend beyond the bases of the metacarpals: the muscle as well as the tendon is superficial. In *Macroglossus minimus* its principal origin is radial, and its insertion is by two tendons, one into the base of the pollex metacarpal, and one which stretches to the base of the first phalanx of the index. Professor HUMPHRY found in *Pteropus Edwardsii* that one tendon of this muscle was inserted into the sesamoid bone on the ulnar side of the metacarpo-phalangeal joint of the pollex, and the other had a slight attachment to the metacarpal bone of the index. and was continued on to the base of the second phalanx of that digit. In *Pteropus edulis* it is also simply metacarpal in its insertion, and sends no distinct slip to any of the phalanges. In *Plecotus* this muscle is of extreme tenuity, and is inserted into the metacarpal bones of the pollex and index; in the Pipistrelle it goes to the first phalanx of the middle and fourth fingers. In *Cephalotes* it springs from the inner condyle, and its tendon is flattened over the rest at the wrist to be inserted into the metacarpal bones of the pollex and index. In *Rhinolophus speoris* and *diadema* its insertion is threefold, into the pollex, medius, and index; the slip to the index is very thin, the origin is superficial, and the fleshy portion very short. In *Megaderma* it is slender, and its tendon is tightly tied to the next; its muscle is deep, arising from the radius; its insertion is into the thumb, index, and middle fingers, at their metacarpo-phalangeal articulations: the tendons in all are flat, superficial, and in the last especially they are lost in the fascia and are not attached to bone. In *Artibeus* the arrangement is as in *Vampyrops*; in *Cynonycteris* it is attached as in *Cephalotes* (Plate XIV. figs. 1, *l*, 2, *a*, & 3, *d*).

Taking together the flatness and fascial connexion, the metacarpal insertions and superficiality at the wrist, where this tendon runs in a separate sheath under a thin band of fibrous tissue, but over the main body of the annular ligament, all these together seem to indicate that it is a palmaris, not a flexor sublimis. The existence of a pollical slip is not what we might expect in a flexor sublimis. In *Noctulina* this muscle is absent altogether.

Flexor digitorum communis (Plate XIV. figs. 1, *d*, 2, *h*, 3, *g*, & 5, *e*) (profundus of HUMPHRY) in *Noctulina* arises from the inner condyle, from the upper third of the radius, and is inserted into the base of the first phalanx of the pollex, into the second phalanx of the medius, and the origin of the interosseous muscle for the pollical side of the ring-finger. In *Pteropus Edwardsii* and *medius* it arises from the inner condyle, from the radius and ulna; it passes under a strong arch at the wrist to be inserted into the last phalanx of the pollex, into the index and middle fingers at their last phalanges; the tendon to the middle finger in the female *Pteropus Edwardsii* became fleshy for a considerable part of its extent (HUMPHRY). In *Pt. edulis* it was as in the other species, but no part of the tendon became fleshy.

This is the only long flexor muscle of the digits present in most of the Vespertilionine Bats, as Professor AEBY describes (*l. c.* p. 66). In *Vampyrops* it arises from the condyle, upper third of the radius and ulna; its tendon passes under the transverse process of the os magnum, and is inserted into the pollex and medius, extending to the terminal

phalanges of each. In *Macroglossus minimus* it is inserted into the pollex and index, and by a fine thread forming the origin of the polliceal interosseous of the middle finger. In *Plecotus* it is also inserted into the pollex and index. In *Vesperugo* and *Vespertilio* it is similar. In *Cephalotes* its origin is as in *Vampyrops*, and its insertion as in *Macroglossus*. In *Megaderma* its origin is merely condylo-radial, and the insertion by three tendons into pollex, medius, and ring, the last tendon being very feeble; it is the same in *Rh. speoris* and *diadema*, only the ring tendon goes to the radial interosseous of that digit. CUVIER says this muscle has five slips to the five fingers, MECKEL says four; both of which statements are incorrect, as will be seen. In *Artibeus jamaicensis* its origin is from the humerus, radius, and ulna, and its insertion into the pollex and medius. In *Cynonycteris amplexicaudatus* it is very similar to the arrangement in *Cephalotes*.

In the left forearm of my specimen of *Vampyrops vittatus* I found a special flexor annularis, as a small thread of muscle ending in a slender tendon which passed to the last phalanx of the ring-finger; it was only found in this specimen and in the *Cephalotes*, and seemed like a detached slip of the flexor profundus digitorum.

Extensor carpi radialis longior (Plate XIV. fig. 4, *j*) is separate in all except *Plecotus*, *Scotophilus*, and the Pipistrelle; in the others it had a perfectly simple and normal course, and was inserted into the base of the second metacarpal bone; it is the smaller of the two, and of course the more superficial; the radial nerve lies in front of it.

Extensor carpi radialis brevior (Plate XIV. fig. 4, *k*) is equally constant and has its normal insertion. I found no sign in any species of the extension of accessory slips from this tendon to the fourth and fifth metacarpal bones, like those described by Professor HUMPHRY; so I suppose that they also should be considered as muscular anomalies, especially as it was only in one of his specimens (male) that he found them. MECKEL describes this muscle as inserted into the three outermost metacarpal bones, but I found no fibres in any species extending to the polliceal metacarpal.

Extensor carpi ulnaris (Plate XIV. fig. 4, *a*) is a very small muscle when present, and I missed it in the smaller Vespertilionine specimens. In *Megaderma* and *Rhinolophus* it is extremely small; it is in all principally ulnar in its origin, entirely so in *Noctulina*, condylo-ulnar in the others; it is inserted into the fifth metacarpal in most, into the fourth and fifth in *Noctulina*, into the same bones in *Artibeus* and in *Cynonycteris*, extending to the first phalanx in *Cephalotes*; it is purely metacarpal in insertion in *Macroglossus*.

Extensor ossis metacarpi pollicis (Plate XIV. fig. 4, *f*) is constant in all the Cheiroptera, and displays no remarkable feature, arising high upon the back of the forearm from the ulna and radius; its tendon passes, as usual, over the radial extensors of the carpus, and in most of the species is inserted into the base of the metacarpal bone of the pollex simply. A sesamoid bone exists in almost every species at the lower end of the tendon where it lies on the wrist-joint. In *Cephalotes* it rises as high as the elbow-joint, to the external ligament of which some of its fibres are attached. In *Megaderma* it has a large radial attachment. I found no special insertion into the radial extremity of the transverse process of the os magnum in any species; but in some of the large ones, as

Pteropus edulis, a fibrous band connected the sesamoid bone to it; still in these, as in the others, the main insertion is into the pollex metacarpal. The sesamoid bone is very large in some of the species, and has a distinct articular facet for the scapho-lunar in *Eleutherura*: I did not find it in *Scotophilus hesperus*; but the parts are so small that I may have easily missed it (CUVIER says of this muscle that it crosses the extensor carpi ulnaris at the wrist; but this is obviously an error).

Extensor secundi internodii pollicis arises from the back of the radius at its lower half; it crosses the radial extensors at the wrist, and is inserted as usual. In *Vampyrops* I missed it in the left arm, but found it in the right. In *Megaderma* it springs from the olecranon, but it is very large in *Rhinolophus diadema*. In all the other specimens it is normal and large.

Extensor indicis is a separate muscle in all but *Megaderma* and *Cephalotes*, in which it is joined to the extensor digitorum; it arises from the radius and is inserted into the last phalanx of the index, but only into the metacarpal bone in *Megaderma*. The existence of this muscle was not recognized by MECKEL or CUVIER, and AEBY says that he failed to find it in the Bat (*loc. cit.* p. 60).

In *Macroglossus minimus* I found this muscle replaced by an extensor of the pollex and index, similar to the muscle which exists in the Dog, Fox, Panther, and Wolf. It arose below the extensor ossis metacarpi pollicis, and was inserted into the first phalanges of the pollex and index. In *Cynonycteris* and *Plecotus* I found a corresponding muscle coexisting with the extensor indicis and the extensor secundi internodii pollicis, but I have not found it in any other species.

Extensor digitorum communis arises from the outer condyle of the humerus as well as from the radius; it passes along the ulnar side of the forearm, and at the wrist projects to the ulnar side; it ends in three tendons, which pass to the three ulnar fingers. In *Megaderma* the tendon for the second finger is very weak; in *Cephalotes* the extensor indicis is slightly joined to it; the union is more close in *Megaderma*. CUVIER describes this muscle as inserted into the last phalanges of all the fingers, but in none does this muscle proper send a tendon to the index. As all the tendons cross on the ulnar side of the wrist, that for the middle finger crosses the back of the fifth, fourth, and third metacarpals, that for the fourth crosses the fifth and fourth, and so on.

The muscles of the manus are as follows. For the pollex I have found:—

1st. An abductor pollicis (Plate XIV. fig. 5, *g*), from the scapho-lunar to the base of the first phalanx of the pollex; on its outer side this is present in *Macroglossus*, *Pteropus*, *Noctulina*, *Megaderma*, and the other large Bats.

2nd. Opponens pollicis, arising from the trapezium and scapho-lunar bones, inserted into the metacarpal bone of the pollex; this I have only found in *Noctulina* and *Macroglossus*.

3rd. Flexor pollicis brevis radialis, from the scapho-lunar bone and from the radial side of the os magnum to the base of the radial side of the first phalanx of pollex; it is

present in all the species, and is large in *Noctulina*, *Cephalotes*, *Megaderma*, and *Eleutherura*: this muscle is always separate from the foregoing.

4th. Flexor pollicis brevis ulnaris, from the os magnum to the ulnar side of the first phalanx, is also always present.

5th. An adductor pollicis is present in *Macroglossus* and *Megaderma* as a small transverse bundle from the second metacarpal to the base of the first phalanx of the pollex.

For the little finger there are in nearly all Bats the following muscles:—1st. Abductor from the unciform; in *Megaderma* it arises from the palmar ossicle, and in *Macroglossus* and *Cephalotes* from a thread of the tendon of the flexor carpi ulnaris; it is inserted into the first phalanx of the little finger. 2nd. Opponens minimi digiti is very small and rudimental in *Macroglossus*, absent in most of the others, and existed in that species as a thin filament from the carpus to the metacarpal bone. 3rd. Flexor brevis minimi digiti is the radial interosseous muscle for this digit: its origin is peculiar; it springs from the extremity of the transverse process of the os magnum, it lies superficial to the origins of the other interossei muscles and to the tendon of the flexor profundus digitorum et pollicis under cover of the palmaris longus, and it is inserted into each side of the second phalanx by a split tendon.

For the index-finger there is an opponens, or a metacarpal flexor, in *Noctulina*; there are in the others two interossei present.

For the middle finger there are also two interossei; one of these in *Macroglossus*, as already described, arises from the flexor digitorum tendon, the other arises from the os magnum and trapezoidale. In *Noctulina* these two muscles are combined, but the tendon is double; in the same species this muscle arises in common with the interosseous for the ring-finger, which is also single, as it is in all the species, but has a double tendon. There are no anconei muscles in the forearm, nor is there any palmaris brevis in the hand. The thumb-muscles are supplemented in their action by the occipito-pollicalis above described.

Muscles of the Abdomen.

Both in males and females the abdominal wall-muscles are very thin, and invested by a strong elastic layer of fascia, which lays immediately under the skin; from this arises the pectoralis quartus, and under it is the external oblique, which arises from the five or six lower ribs, indigitating with the serratus magnus; it soon becomes tendinous, and is inserted over the rectus into the linea alba; its lower border forms a strong Poupart's

The internal oblique and transversalis combined form one inseparable muscle (except in *Pteropus*, in which they are for the upper half of the abdomen perfectly separable), which underlies the last, and passes behind the rectus. Its origin is from the lumbar fascia and ilium, and apparently from the lower margin of the lowest rib; its insertion is into the linea alba; none of its fibres go in front of the rectus. For the lower quart f the abdomen these muscles are very thin and fascial in nature. Piercing its

lowest border is the spermatic cord, which appears to pass under, not over, Poupart' ligament; but of this I am not sure.

Rectus abdominis is the largest of the abdominal muscles, and is placed between th two before mentioned; it arises from the pubis by a narrow fleshy head, rapidly widen and ascends to be inserted into the first rib in *Pteropus*, *Macroglossus*, *Plecotus*, *Cephalote* *Eleutherura*, *Cynonycteris*; into the fourth, fifth, and sixth ribs in *Vampyrops vittatus* into the third, fourth, fifth, sixth, and seventh rib-cartilages in *Artibeus*. In the female a space intervened between the two recti above the pubis. HUMPHRY (*loc. cit.* p. 302) an MECKEL say that no tendinous intersections exist in this muscle; but in *Pteropus* there i a complete intersection under the origin of the pectoralis quartus about half an inc below the ensiform cartilage. In *Cephalotes* there is one well-marked linea transvers immediately below the ensiform cartilage. In *Eleutherura* there is one partial line i this position, and a complete one a quarter of an inch above.

MECKEL describes this muscle as being inserted into the ensiform cartilage, into th cartilages of the fifth and sixth ribs, and says that they send a wide straight slip to th humerus; here he has evidently fallen into the mistake of regarding the pectoral quartus as being connected with this muscle; in no species is it connected to the ens form cartilage.

Pyramidalis is very thin and small, only present in the large Pteropine Bats. MECKI states that it is absent, and, indeed, it is indetectable in the smaller species. Profess HUMPHRY and I have found it very strong in *Pteropus Edwardsii* and *edulis*, its low fibres being nearly transverse in the female.

The diaphragm has a wide costo-xiphoid deficiency in *Cephalotes*, and is closely attach to the liver by a wide coronary ligament. The crura are very large, especially in *Meg derma*; the muscular fibres are long, the tendon in the centre small. CUVIER notices tl great size of the crura, which are placed like a vertical fleshy septum in the abdome In *Pteropus edulis* this is especially the case.

Quadratus lumborum is not absent as CUVIER supposes, but is long and thin, co sisting of two sets of fibres, ilio-costal and ilio-lumbar; the latter, as usual, internal ar larger; there are no lumbo-costal fibres; the second set pass to the three upper lumb vertebræ in *Megaderma*. In none of the other species does this muscle present ar features of interest.

Psoas parvus is present in all, and generally large, as CUVIER remarks (Leçons, i. p. 349 MECKEL also notices its presence, and gives as its origin the first lumbar vertebra. I *Noctulina* it has a short muscular part and a long tendon. In *Cephalotes* it is muc larger. In *Megaderma* it is very thick, short, and fleshy for its whole extent. I insertion in all is into the prominent spine of the pubis. In all its origin is limited t one or two vertebræ; HUMPHRY gives two or three dorsal and the same number c lumbars, and says some fibres are continuous into the pectineus. I was, however, abl with care to separate it from this muscle in all my specimens.

Muscles of the Lower Limbs.

The position of the parts in these limbs is so remarkable that a brief review of the arrangement is necessary before describing the muscles. The variation in position from the usual disposition of hind limbs in Mammalia may be described as twofold. 1st, the limbs instead of having suffered a rotation forwards from their embryonic position, have been rotated backwards, and this has caused the following peculiarities: the knee-joints are directed backwards and outwards, the tibial side of the leg inclines outwards and forwards, the fibular side inwards, the plantar surface of the foot is directed forwards, the outside of the femur is directed backwards and a little inwards, the adductor aspect of that bone looks forwards and outwards; of its two tuberosities the lesser or tibial is external and anterior, the greater or fibular is internal and posterior; the head of the fibula is defective. This remarkable disposition of parts, it will be seen, is precisely similar to the usual arrangement in the fore limb, and the guides to homologies derived from it are of extreme value. With the knee in the position of the elbow, the ulna and fibula, radius and tibia are thrown into precisely similar positions; so are the great toe and the pollex, the external condyle (humerus) and the inner condyle (femur), and *vice versâ*, the great trochanter and the lesser humeral tuberosity, the lesser trochanter and the greater tuberosity. Thus the system of homologies which GOODSIR proposed, and which after him has been supported by HUXLEY, MIVART, FLOWER, and HUMPHRY, receives an immense support from this arrangement.

The second peculiarity in the hind limbs of the Cheiroptera is the position of the pelvis. The ala of the ilium is everted, so that the iliac fossa is anterior and external, the ilia rod-like, the pubes and ischia project forwards, and the lower outlet looks forwards.

From these peculiarities in position it can easily be understood that the hind-limb muscles in some respects depart from the usual mammalian positions in some respects, as will be seen hereafter.

Psoas magnus is a large muscle arising from the three uppermost lumbar vertebræ except the first in *Cephalotes*, from the lumbar vertebræ, sacrum, and side of the ilium in *Megaderma*, from the vertebræ and margin of the ilium in *Cynonycteris*. In *Artibeus* the muscle arises as in *Megaderma*, in *Pteropus edulis* it is attached to the lower lumbar vertebra only. Professor HUMPHRY describes it in his specimen of *Pt. Edwardsii* as arising from the lumbar vertebræ external to the psoas parvus, from the front of the sacrum and from the ilium, passing under the pubic spine to the anterior trochanter of the femur. MECKEL says its origin is from all the lumbar vertebræ; and CUVIER, strangely enough, states that this muscle does not exist (Leçons, i. p. 359).

Gluteus maximus (Plate XIV. fig. 14, *h*) is triangular and flat; it arises from the posterior border of the crest of the ilium and sacral spines in *Pteropus Edwardsii* and in *Megaderma*, from the sacrum alone in *P. edulis*, from the sacrum and first caudal vertebra in *Noctulina*, from the sacrum in *Cephalotes*, from the ilium and sacrum in *Artibeus*, from the sacrum and upper two caudal vertebræ in *Cynonycteris*; it is inserted into the upper half of the thigh in *Noctulina*, the upper third in *Megaderma* and *Rhinolophus* as well as

in *Cynonycteris*, to less than the upper third in *Pteropus*, more than half in *Macroglossus* and *Eleutherura*.

Gluteus medius (Plate XIV. fig. 10, *a*) is the usual thick external pelvic muscle, and occupies in all the outer side of the ilium. In *Plecotus* it is short and thick, in the Pipistrelle it is long and narrow, much thinner in *Pteropus*, triangular in *Artibeus*, and very thick in *Cynonycteris*; its insertion in all is into the posterior trochanter. Meckel describes it as a small muscle; but it is larger than the gluteus maximus; the gluteus minimus is absent in all, as Meckel remarks; Cuvier mistook the iliacus for it.

Gluteus quartus (Plate XIV. fig. 10, *c*) exists as a separate marginal muscle in the Pipistrelle, in the Vampyre, *Megaderma*, and *Rhinolophus*. None is present in *Noctulina*, *Plecotus*, *Cephalotes*; where it exists it passes from the margin of the ilium in front of the gluteus medius, and is inserted in front of the external trochanter.

Pyriformis (Plate XIV. fig. 13, *c*) is not a distinct muscle in *Vampyrops*, *Cephalotes*, and *Noctulina*, but in *Megaderma* and *Eleutherura* it exists as a separate muscular band above the sciatic nerve; it is the same in *Rhinolophus*, and partly separate at its origin in the Kiodote. Cuvier says it is absent (Leçons, i. p. 359); Meckel confounds the next muscle with this. In *Artibeus* it is united to the gluteus.

Caudo-femoralis (Plate XIV. fig. 10, *e*, *f*) (gubernator caudæ, Haughton) is a muscle which passes from the first caudal vertebra to the external part of the upper point of trisection of the femur; it is thick and strong in *Plecotus*, absent in the Pipistrelle, double in *Vampyrops*, crossing the insertion of the gluteus medius. In the Noctule it arises under the extensores caudæ from the first and second caudal vertebræ, and is inserted into the upper two fifths of the outside of the lower border of the femur, lying over the tendon of the gluteus maximus. In *Cephalotes* it is small, thick at its origin, and inserted into the middle of the femur. In *Megaderma* it is very large, and springs from the sacrum and two caudal vertebræ. It is double and largest of all in *Rhinolophus diadema*; it is also double but smaller in *Macroglossus*. Meckel takes this to be the pyriformis; but it is quite separate, and has the same relation to the pyriformis that the latissimus dorsi bears to the teres major.

Quadratus femoris (Plate XIV. fig. 12, *h*) is perfectly distinct in all the species, arising below the obturator muscle and passing from the tuber ischii to the root of the great trochanter. It is small in *Noctulina*, larger in *Cephalotes* and *Macroglossus*. Cuvier says it does not exist.

Iliacus internus (Plate XIV. figs. 7–9, *d*, 10, *b*, 11, *a*) is a very remarkable muscle, having a purely external origin, springing from the outside of the ilium close to the crest, external to the psoas, and separated from the gluteus medius by the extensor cruris; it is inserted into the anterior trochanter; it is parallel to the psoas in general, very small in *Megaderma*. Cuvier says it is absent (Leçons, i. p. 357). It is exceedingly constant, and exhibits no other features of interest in any species.

Gracilis (Plate XIV. fig. 7, *e*) is the largest of the internal or anterior femoral muscles, and has usually a wide origin; in *Megaderma* it overlies the adductors and arises from the

whole of the margin of the pubis and ischium; it very soon becomes tendinous, and is inserted into the anterior aspect of the tibia two lines below the head. In *Plecotus* and *Vesperugo* it is the same. In *Noctulina* it is larger and with longer fibres, and inserted one eighth below the head of the tibia. In *Cephalotes* it is smaller, springing from the ilio-pectineal line, and inserted as usual; in this animal (Plate XIV. fig. 11, *h*) there is a separate slip of this muscle which springs from the pectineal point to be inserted along with the rest of the muscle; at its origin it lies between the gracilis and the pectineus, and is superficial to the last: possibly this slip might represent the sartorius; if we take into account that in some Artiodactyls and Edentates this muscle undoubtedly does arise from the pectineal eminence, it gives some colour to the supposition. If this be not the sartorius there is then no trace of that muscle in the entire series; this is the case also regarding the tensor vaginæ femoris, of which no Bat shows the slightest trace. The tendon of the gracilis in no species joins inseparably that of the hamstring, but, as HUMPHRY found in his individuals of *Pteropus Edwardsii*, there is in the three species of this genus a slight adhesion. CUVIER groups this muscle and the hamstrings together as a bicipital single muscle.

Pectineus (Plate XIV. fig. 8, *i*) lies under the gracilis, or posterior to it; it arises from the horizontal ramus of the pubis, and is rounded at first (HUMPHRY); its insertion is immediately below the tendons of the psoas and iliacus. In *Noctulina* it is higher up than in most of the others, not covered, only overlapped by the gracilis; it is very small in *Megaderma*, larger in *Macroglossus*. In *Pteropus edulis* it is excessively small, indeed least of all; in *Artibeus* it is largest, in *Cynonycteris* intermediate in size.

In the Pipistrelle there is but one adductor, as in *Plecotus*, *Vampyrops*, *Synotus*; this arises from the pubis and ischium between the last and the obturator externus; its insertion is into the anterior part of the thigh, below the pectineus for a varying extent. This muscle is bilaminar in *Pteropus Edwardsii*, very faintly so in *edulis*; the upper part or adductor brevis is small, the lower or magnus extends three fourths down the bone. In *Noctulina* it is much the same, the fibres extending for the upper half of the femur. In *Cephalotes* and *Macroglossus* (Plate XIV. fig. 8, *j*, *k*) the muscle is bilaminar also, and extends to the same distance; and this is the case in *Megaderma* and *Eleutherura*. MECKEL and CUVIER only recognize a single adductor, which they say only extends to one third (CUVIER) or one half (MECKEL) of the thigh. HUMPHRY conjectures that the pectineus may contain in it the germ of the adductor longus. An upper part of this muscle HUMPHRY supposes might be a quadratus femoris, and an external part separated by the sciatic nerve he supposes might be a biceps; but there scarcely exists any anatomical ground for this division.

The biceps muscle is absent in all the Bats, as noticed by all anatomists.

Obturator externus (Plate XIV. fig. 9, *m*) arises from the outside of the obturator foramen, winds round as usual, and is inserted into the trochanteric fossa; it is square in *Vampyrops*, triangular in *Noctulina* and *Cephalotes*, very small and in two bands in *Megaderma*.

There is no obturator internus, except in *Megaderma*, in which a few fibres of the gemellus extend to the inner side of the obturator membrane.

Gemellus exists, in *Pteropus*, *Megaderma*, and *Vampyrops*, as a band of fibres from the tuber ischii to the trochanter above the obturator externus; it is absent in the other genera.

Rectus femoris (Plate XIV. fig. 13, *d*) has a single iliac head in *Eleutherura*, has two, as usual, in *Noctulina*, *Vampyrops*, *Cephalotes*, *Macroglossus*, *Megaderma*, in the last of which it is largest of all proportionally; it joins the rest of the extensor at the middle third of the thigh, and is inserted with it.

Extensor cruris femoralis (cruræus, Plate XIV. fig. 13, *e*) is but a single band in all the Bats, which arises from the upper fourth of the femur, and joins the last to be inserted into the tubercle of the tibia; the tendon crosses the knee, but has no patella in it. This muscle is largest in *Megaderma*, in which there is an obscure sign of a division.

Semitendinosus (Plate XIV. fig. 14, *f*) is the most posterior and internal of the two hamstrings; it arises from the back of the tuber ischii, and is inserted separately below and behind the semimembranosus. In *Cephalotes* it is small, and has a caudal origin; it has a long tendinous origin and a longer tendinous insertion in *Megaderma*. In *Pteropus* it has a caudal origin and is penniform; but in none does it present the curious inscription found in the higher Primates.

Semimembranosus (Plate XIV. fig. 14, *g*) in *Noctulina* is once and a third larger than the last-named; its insertion is above and in front of the last; its origin is also ischiatic, and it is larger than the last in *Cephalotes* and *Eleutherura*. In *Rhinolophus* these two muscles, though double at origin, have only a single insertion; and in *Megaderma* the semimembranosus is either absent or fused with the gracilis. In *Pteropus* its insertion is slightly joined to that of the gracilis, and its origin is purely ischiatic.

The leg-muscles are in the smaller Bats exceedingly small and difficult to be separated; the flexor aspect is directed forwards, and there is no trace of popliteus, soleus, or plantaris in any, with one exception, viz. on the back of the knee in *Vampyrops* I found a few oblique fibres like a rudimental popliteus (Plate XIV. fig. 17, *b*). MECKEL says there is a soleus, but this is an obvious mistake. The gastrocnemius is a very delicate muscle with two heads, except in *Megaderma* (which has only an inner head); these are from either condyle, and the external head, or that from the tibial condyle, has a sesamoid bone (Plate XIV. fig. 16, *c*) in most species except *Noctulina*. This muscle lies at the inner part of the leg, has a long tendon, and ends in the os calcis.

The digital flexors are two in number as usual. The flexor digitorum longus arises from the upper part of the back of the tibia; it passes down the outside of the leg, and is crossed by the tendon of the tibialis posticus; having passed the os calcis, it is joined by the next muscle: it is small in *Cephalotes*, still smaller in *Megaderma*, largest in *Eleutherura*.

Flexor hallucis longus arises from the fibula for its whole length, and from the slender

fibrous thread above the summit of that bone (which is not complete up to the knee); it meets the last muscle at the ankle, and the two tendons fuse. In *Noctulina* they are equally distributed to the five toes. In *Macroglossus* this muscle supplies the entire of the great toe, sends a fine thread to the fifth, forms fully half the tendon to the second and fourth, and sends an exceedingly thin filament to the third; this toe, half the second and fourth, and the fifth are supplied by the tibial flexor; this extends up to the femur in *Megaderma*, and in this the tendons are blended indistinguishably, except that the inner toe is only supplied by this muscle. In this animal likewise a thread of muscle passes from the os calcis to the tendon, forming the only rudiment of an accessorius with which I have met in the order (HUMPHRY found none in the *Pteropus*).

Tibialis posticus is very small, and springs from the middle of the back of the tibia, passing to the sesamoid bone behind the ento-cuneiform in *Noctulina*, or to the scaphoid in *Macroglossus*, or to the inner cuneiform in *Megaderma*; it occasionally gets a little accession of fibres from the fibula, as HUMPHRY found in *Pteropus*. MECKEL says this muscle does not exist.

Peronæus longus arises from the fibular condyle of the femur in *Noctulina*, descends to the inner side of the ankle receiving fibres from the fibula, and is inserted into the plantar surface of some of the tibial metatarsal bones (how many I could not say). In *Cephalotes* it does not rise to the femur, but has the same insertion. In *Pteropus Edwardsii* it is inserted into the second metatarsal bone; in *Pt. edulis* it is inserted into the first and second; in *Macroglossus* it is attached to the second metatarsal.

Peronæus brevis is the only peroneal muscle present in *Megaderma*, and passes from the lower half of the fibula to the fifth metatarsal at the external side of the ankle. In *Macroglossus* it passes from the external condyle of the femur to the projecting spur on the cuboid bone; in *Eleutherura* it passes to the fifth metatarsal, sending a peronæus quinti slip to the base of the first phalanx. MECKEL found one peronæus only, and this is the case in the majority of species. Professor HUMPHRY describes a peronæus tertius coexisting with the longus in *Pteropus*, arising from the front of the fibula, and inserted into the metatarsal bone of the fifth toe, with a slip to the extensor tendon of this toe; in his male specimen this is the peronæus brevis, similar to the only peroneal muscle in *Eleutherura*; its *brevis* nature is much more plainly seen in the other species of *Pteropus*, where its tendon is clearly postmalleolar.

Extensor digitorum longus arises in all from the front of the femur by a slender tendon, and from the outer surface of the tibia above the tibialis anticus; its tendon passes in a special groove in the annular ligament, and divides on the dorsum of the foot into four slips, which pass to the dorsum of the four outer toes; this is the arrangement in *Noctulina*, *Macroglossus*, and *Cephalotes*. There are five tendons in *Megaderma*, *Eleutherura*, and *Rhinolophus*.

Tibialis anticus arises from the outside (posterior aspect) of the tibia for its lower half (*Pteropus* and *Megaderma*), two thirds (*Macroglossus*), middle third (*Eleutherura*), or lowest third (*Noctulina*); it is inserted into the metatarsal bone of the hallux in most

species, but only extends into the scaphoid and internal cuneiform in *Megaderma* and *Macroglossus*.

Extensor hallucis longus exists as a separate muscle only in *Macroglossus*; it is very slender, and passed from the interosseous border of the tibia to the hallux. I found no trace of it in any other species.

The dorsum of the foot presented two muscles:—

Extensor digitorum brevis, which in all was moderately strong and passed from the outer side of the tarsus to the four fibular toes. Separate from this in all was the extensor hallucis brevis, which arises from the lower end of the tibia and front of the tarsus, and is inserted into the great toe; this is largest in *Noctulina* and *Eleutherura*.

In the sole of the foot are the following muscles:—

Levator ossis styliformis, a slender muscle from the back of the lower part of the ankle to the upper surface of the styliform bone. This muscle is small, and proportionally largest in *Noctulina*.

Depressor ossis styliformis (styliform muscle of HUMPHRY) starts from the plantar surface of the calcaneum (*Noctulina*), or from the fifth metatarsal bone (*Pteropus* and its allies), to the lower border of the spur.

Abductor minimi digiti, abductor ossis metatarsi minimi digiti, and abductor hallucis were present in all, and displayed no features of particular interest. The flexor brevis digitorum in all divided into four slender bellies, whose tendons supplied the four digits on the fibular side; it was small in *Pteropus*, larger in *Macroglossus*. There were eight lumbricales: one of these arose from the flexor hallucis tendon, and supplied the inner side of the great toe; one arose from the flexor digitorum longus tendon, and supplied the fifth toe on its tibial side; and for each of the other toes there were two, one from the flexor hallucis tendon, and one from the flexor digitorum longus.

The transversalis pedis was very large and double in *Macroglossus*, single and large in the others; in *Pteropus* it was very wide, and stretched from the fifth metatarsal bone and from the first phalanx of this digit, from the fourth and partly from the third metacarpal bones, into the metacarpal bone and first phalanx of the hallux. Professor HUMPHRY, in his description of this muscle, regards its halluceal attachment as its origin, and its minimal attachment as insertion.

There are ten single-headed interossei, one on each side of each digit.

For purposes of comparison I have dissected two other types of so-called flying Mammals: one the *Pteromys volans*, or Flying Squirrel, of the order Rodentia; the other *Galeopithecus volitans*, or Flying Lemur, of the order Insectivora. As an appendix to the Myology of the Cheiroptera I shall briefly state the muscular peculiarities met with in these species.

In *Pteromys* the cutaneous muscles were:—1st. Carpo-tarsal (Plate XVI. fig. 1, *f*), a strong cord of muscular fibres extending in the margin of the plagiopatagium from the tip of the styliform bone of the carpus to the inner side of the tarsus, and more parti-

cularly to the lower end of the tibia. 2nd. Carpopatagial (Plate XVI. fig. 1, *g*) consisted of radiating fibres starting from the carpal spur, and passing backwards and inwards to be lost in the wing-membrane. 3rd. Coraco-patagial (Plate XVI. fig. 1, *h*), a strong band starting from the tip of the coracoid process, and lost in the plagiopatagium by spreading along with the last. 4th. Coraconotal, deeper and further back than the last, arising, like the dorsi patagial of the Bats, from the integument over all the dorsal spines, and inserted into the coracoid process under the last; this muscle also arises from the fascia over the lower half of the lateral aspect of the thorax, and in it ramify the lateral cutaneous thoracic nerves. 5th. Transversus nuchæ (Plate XVI. fig. 1, *a*), a singular muscle, which I think is the same as the muscle described under this name by Professor F. E. SCHULTZE, of Rostock, joined to the zygomaticus major; it arises immediately below the occipital line from the median line of the back of the neck over the deep cervical muscles, passes forwards and crosses the next muscle to be inserted into the middle of the margin of the lower lip; it runs transversely, lying on the splenius, the next muscle, the masseter, and the ramus of the mandible.

The sixth of the cutaneous muscles is the most remarkable; it may be named jugo-pollicalis (Plate XVI. fig. 1, *b*, *c*): it arises from the zygomatic arch by a flat wide expansion; crossing under the transversus nuchæ, it is inserted into the base of the rudimental pollex; it is only fleshy for about half its course, and it runs in the propatagium.

It is easy to see of these muscles that the last is of the same nature as the continued portion of the occipito-pollicalis, together with the platysma myoides superior; as there is a rudimental occipital trapezius, there is no occipito-pollicalis proper; the others, with the exception of the first and fifth, have their representatives among the Bats, and the nuchal slip of some of the Cheiroptera may be a depressed transversus nuchæ. I could not trace any filaments of the spinal accessory into any part of this group of muscles.

Pectoralis major is divisible into two parts; one of these arises from the upper half of the sternum and the inner half of the clavicle, the other from the lower half of the sternum: it is inserted as usual, and is a small muscle in comparison with its namesake in the Bat.

Pectoralis minor arises from the third, fourth, and fifth rib-cartilages, crosses over the coracoid process to be inserted into the upper part of the greater tuberosity of the humerus. A distinct fourth pectoral arises from the fascia over the ensiform cartilage and upper fifth of the abdominal linea alba, crosses the tendon of the pectoralis minor to be inserted into the humerus even higher up than that muscle.

The clavicular and acromial deltoids are united, and make one small muscle with short fibres, which only occupies a very small section of the outer extremity of the clavicle, and is inserted high up on the humerus; the scapular deltoid lies over the infraspinatus exactly as in the Bats, and its insertion has the same relation to the foregoing muscle as in the Cheiroptera.

Sterno-cleido-mastoideus is not separable into its components, except at its origin; and its insertion is into the paroccipital and into the whole length of the supraoccipital transverse ridge.

The omo-hyoid is large and monogastric, the sterno-hyoids and thyroids simple and large; the digastric has two separate bellies and a central rounded tendon, which is continued from side to side above the hyoid bone as an arch, from which the parallel anterior bellies arise.

The levator claviculæ arises from the middle cervical transverse processes, and passes to the outer extremity of the clavicle and the acromion process. The latissimus dorsi springs from the nine lowest dorsal vertebræ, from the lumbar fascia, and from the three lowest ribs; it is inserted as usual, but its costal portion sends a thick band up to the coracoid process under the coraco-cutaneous and notocoracoid muscles; it is closely tied to the teres major, and the enormous dorsi epitrochlear muscle arises nearly equally from both.

Trapezius is indivisible, and arises from the ligamentum nuchæ, from the inner fifth of the occipital ridge, and from the six upper dorsal spines; its upper part is wide and its lower narrow, and its insertion is as usual. The rhomboid is in two parts; the occipital portion descends nearly vertically and is inserted into the vertebral edge of the præscapula and mesoscapula. On the left side this muscle was in two bands, one arising from the middle line of the occipital bone and inserted into the mesoscapula, the other from the outer third of the supraoccipital ridge and attached to the præscapula; these were continuous on the right. The levator anguli scapulæ arises from the transverse processes of the fifth and sixth cervical vertebræ, and is separated from the last by a fatty mass.

Serratus magnus is divided into two parts, an upper, which is attached to two ribs, and a lower, which extends from the third to the eleventh ribs; this latter part is inserted into the inferior angle of the scapula only; the upper is perfectly separate from the levator anguli scapulæ.

The subclavius is perfectly separate from the sterno-scapular, which overlies the supraspinatus, and is attached to the mesoscapula, the subclavius proper going to the clavicle. The scalenus anticus is large and is inserted into the first rib; the medius and posticus are inseparable, and are attached to the four uppermost ribs. The rectus abdominis ascends to the first rib; the serratus posticus superior is inserted into the upper five ribs below the first, and the inferior into the five lowest. I could find no trachelo-mastoid; but otherwise the deeper neck-muscles were normal, the complexus having no tendinous intersection.

The subscapularis was not nearly so large as in the Bats, and had three tendinous septa in it; there was no subscapulo-humeral separate; the supraspinatus is three times the size of the infraspinatus.

Dorsi epitrochlearis is a large fleshy muscle arising from the tendons of the latissimus dorsi and teres major (rather more from the latter than from the former). It overlies the triceps, is fleshy and thick for its whole length, and is inserted into the inner side of the olecranon process.

Biceps has a small coracoid head joined to the whole length of the coraco-brachialis

longus; the long head crosses the shoulder-joint, with which its bursal sheath freely communicates; the two parts of this muscle join inseparably. The brachialis anticus is large, and extends as high as the neck of the humerus on its outer side. There are two coraco-brachiales: a coraco-brachialis longus (WOOD), extending for the lower half of the bone, even to the inner condyle, and a brevis, thick and fleshy, closely applied to and crossing over the subscapularis tendon.

The pronator teres extends for the upper half of the radius; the flexor carpi radialis has no second head, and a single tendon inserted as usual; there is no palmaris longus. The flexor digitorum is in three parts, two of which are condyloid and one ulnar. The flexor pollicis has a radial origin, but it unites with the three parts of the flexor digitorum, and I could only detect one set of tendons. There is a very small rudiment of a pronator quadratus, consisting of a few fibres overlying the part where the forearm-bones are united together below; these are traceable in the lower third of the forearm. The supinator longus extends from above the outer condyle to the lower end of the radius. The extensor carpi radialis has a single belly with two tendons; there is no extensor minimi digiti, an extensor ossis metacarpi pollicis, and an extensor indicis; the other forearm-muscles display no features of interest.

In the hinder limb of the Flying Squirrel the muscular arrangements are as follows. The gracilis is thin and narrow, the adductor mass is divisible into the following parts:—pectineus (small and round), adductor longus (with a narrow tendinous origin), adductor magnus condyloideus (closely connected to the semimembranosus), adductor magnus superior, and adductor brevis, all quite distinctly separable. The hamstrings are:—semimembranosus, large and fleshy, attached to the upper sixth of the inner edge of the tibia; semitendinosus, with two heads, one arising under the last from the tuber ischii, the other, as in the Beaver, from the spine of the first caudal vertebra, at first lying superficial to the biceps; both uniting, are inserted below the semimembranosus by a tendinous expansion for nearly the second fourth of the inner side of the tibia; biceps is triangular, arising narrow from the tuber ischii, and inserted into the outer and upper third of the leg.

Agitator caudæ passes from the two foremost caudal spines, and is inserted into the lower half of the outer side of the femur on its flexor aspect, as far as the outer condyle.

Gluteus maximus arises from the sacral spines, and from that of the first caudal vertebra; it is inserted into the third trochanter. Tensor vaginæ femoris is moderately thick, and extends to the upper half of the outside of the femur, being inserted into the fascia as usual; its origin is from the iliac crest. The gluteus medius is thick and separate from the largely developed pyriformis. Gluteus quartus is distinct, marginal, and anteriorly inserted. Iliacus is small, separate from the large psoas magnus; and the psoas parvus is thin and flat. The quadriceps extensor cruris consists of a large rectus with a single iliac origin, an equally large vastus externus, and vastus internus and crureus, partially separable. The tibialis anticus is twice the size of the extensor digitorum, and is single; neither muscle rises to the femur.

Of the three peronæi, the brevis is the largest, then the quinti, then the longus. The outer head of gastrocnemius has a sesamoid bone in its origin, from which arises the plantaris, and to this head further down a slender soleus is attached. The tibialis posticus extends up to the small popliteus. The flexor digitorum is single, with five tendons and four lumbricales. There are two interossei for each digit, pollex and minimus included, an abductor of each of the two lateral digits, but no flexor accessorius nor transversalis pedis; a superficial flexor digitorum with four tendons separates the deep tendons from the plantar fascia.

The specimen of *Galeopithecus* which I dissected was very young, and had been found in the act of sucking its mother when she was shot. I obtained it through the kindness of my friend and former pupil, Dr. MacCarthy, R.N. On account of its youth the dissection was not satisfactory in many points, so I have only recorded such things as were unmistakable.

The trapezius arose from the lower third of the cervical region, from the upper two thirds of the dorsal, and extended in an undivided sheet to the scapular spine; the levator claviculæ was a prominent muscle uncovered by the last, and stretching from the transverse process of the atlas to the outer end of the clavicle. The rhomboid was single, and arose from six dorsal spines; it was inserted into the vertebral edge of the postscapula.

The dorsi epitrochlearis was a very remarkable muscle, and truly verified its name; it arose from the four lowest dorsal spines and extended, fleshy for its whole length, to the inner side of the elbow-joint; it overlay the latissimus dorsi, from which it was perfectly separate. The acromion deltoid was related to the scapular, exactly as in the Bat and the Flying Squirrel, and the latter covered the infraspinatus and teres minor. The triceps longus was single, and its fleshy fibres were short. The cutaneous pollical muscle in the propatagium arose from the mandibular ramus as far as the chin, being thus plainly identifiable with the platysma superior. The teres minor was moderately large; the supinator longus inserted into the upper half of the radius from the lower fourth of the outside of the humerus. The biceps and brachialis anticus were as usual, the coraco brachialis consisting of a medius and a brevis (Wood). The extensor carpi radialis longior and brevior united in their fleshy portions and with two tendons; the extensor ossis metacarpi pollicis separate and strong.

The sartorius arose from the middle of Poupart's ligament, the gracilis from below the spine of the pubis; they both united at their insertions, and appeared very like the muscles in *Cephalotes Pallasii* described above. The three adductors were separable, as was also the pectineus, a very short muscle. The iliacus was marginal in origin and separate from the psoas. A thick carpo-tarsal band extended, as in the Flying Squirrel, in the margin of the plagiopatagium.

The tibialis anticus had a femoral origin, which was very slender, as well as its usual head from the lower two thirds of the tibia; from the same femoral tendon arose the extensor digitorum, and, indeed, the tendon seemed to belong to this muscle more properly

han to the last. There were two peronæi, longus and brevis, a two-headed gastrocnemius, ι flexor hallucis double the size of the flexor digitorum, and a very small tibialis posticus. Che tendons of the flexor hallucis and digitorum appeared to blend inseparably.

As I wish to make this paper a simple record of anatomical facts, I forbear to make ıny comments on the dissections given above; but they will doubtlessly suggest many nteresting lines of thought. The comparison between Bird and Bat myology, between he muscles of the Bats and those of other flying mammals, and the relations of the ınatomical structure of the Bat's fore limb with its method of flight, are all fertile subjects for study, while the importance of the bearing of the displaced hind-limb nuscles in the Bat on serial homology cannot be overrated.

Explanation of the Plates.

PLATE XIII.

Fig. 1. Cutaneous muscles of *Eleutherura marginata*, dorsal aspect.
- *a.* occipito-pollicalis.
- *b.* dorsi patagialis.
- *c.* pubo-cutaneus.
- *d.* femoro-cutaneus.
- *e.* ischio-cutaneus.

Fig. 2. Posterior scalp-muscles of *Megaderma lyra.*
- *a.* occipito-pollicalis.
- *b.* retrahens aurem superior.
- *c.* retrahens inferior.
- *d.* occipito-frontalis, hinder belly.
- *e.* splenius capitis.

Fig. 3. Facial muscles of *Macroglossus minimus.*
- *a.* occipito-frontalis.
- *b.* procerus nasi.
- *c.* dilator naris.
- *d.* orbicularis palpebrarum.
- *e.* attrahens aurem.
- *f.* levator labii superioris.
- *g.* orbicularis oris.
- *h.* zygomaticus.
- *i.* buccinator.
- *j.* depressor labii inferioris.
- *k.* masseter.
- *l.* parotid gland.

Fig. 4. Cutaneous muscles of *Eleutherura marginata*, lateral aspect.
- *a.* occipito-pollicalis.
- *b.* platysma superior.
- *c.* platysma medius.
- *d.* platysma inferior.
- *e.* pectoralis major.

Fig. 5. Facial muscles of *Megaderma lyra.*
- *a.* occipito-pollicalis.
- *b.* spinal accessory nerve.
- *c.* sterno-mastoid.
- *d.* masseter.
- *e.* auriculo-angularis.
- *f.* attrahens aurem.
- *g.* frontalis.
- *h.* orbicularis palpebrarum.
- *i.* levator labii superioris.
- *j.* levator alæ nasi.
- *k.* orbicularis oris.
- *l.* depressor anguli oris.
- *m.* procerus nasi.
- *n.* nose-leaf.

W.H. Wesley lith.

W. West & Co. imp.

Fig. 6. Facial muscles of *Vampyrops vittatus*.

a. lower slip of retrahens aurem.
b. upper slip of ditto.
c. attollens aurem.
d. occipito-frontalis.
e. procerus nasi.
f. corrugator supercilii.
g. orbicularis palpebrarum.
h. levator labii superioris.
i. levator anguli oris.
j. zygomaticus.
k. orbicularis oris.
l. masseter.
m. depressor labii inferioris.

Fig. 7. Posterior deep neck-muscles of *Macroglossus minimus*.

a. origin of occipito-frontalis.
b. retrahens aurem.
c. rectus capitis posticus major.
d, *e.* obliquus inferior capitis.
f. obliquus superior capitis.
g. rectus lateralis.
h. rectus capitis posticus minor.
i. grain of shot in intermuscular space.
j. intertransversalis.

Fig. 8. Cervical muscles of *Megaderma lyra*.

a. masseter.
b. mento-hyoidean.
c. digastric, anterior belly.
d. inscription in digastric.
e. parotid.
f. sterno-mastoid.
g. omo-hyoid.
h. pectoralis major.
i. sterno-hyoid.
j. trachea.

Fig. 9. Superficial dorsal muscles of *Megaderma lyra*.

a. splenius.
b. trapezius superior.
c. deltoideus acromialis.
d. acromion.
e. rhomboideus.
f. trapezius inferior.
g. deltoideus scapularis.
h. teres major.
i. latissimus dorsi.
j. dorsi epitrochlearis.
k. triceps longus anterior.
l. triceps longus posterior.

Fig. 10. Superficial shoulder-muscles of *Vampyrops vittatus*.

a. deltoideus acromialis.
b. acromion.
c. supraspinatus.
d. deltoideus scapularis.
e. teres major.
f. triceps longus.

Fig. 11. Second layer of shoulder-muscles in the same, *a*, *b*, *c*, *d*, *e*, *f* as in the last.

g. humerus.
h. split insertion of the scapular deltoid.

Fig. 12. Third layer of shoulder-muscles in *Vampyrops vittatus*.

a, *b*, *c*, *d* as in figs. 10 & 11.
e. insertion of the scapular deltoid.
f. circumflex humeri nerve supplying the acromial deltoid.
g. filament of the same nerve supplying the scapular deltoid.
h. infraspinatus.
i. teres minor.
j. triceps longus.
k. origin of teres major.

Fig. 13. Anterior arm-muscles in *Macroglossus minimus*.

a. subclavius.
b. subscapularis.

c. subscapulo-humeral.
d. coraco-brachialis.
e. coracoid head of biceps.
f. biceps, belly.
g, *g'*. long head of biceps.

Fig. 14. Long head of front of forearm of *Vampyrops vittatus*.

a. flexor carpi radialis.
b. palmaris longus.
c. flexor digitorum.
d. flexor carpi ulnaris.
e. process of os magnum.
f. flexor brevis minimi digiti.
g. interossei of annularis.
h. ulnar interosseus of medius.
i. radial interosseus of medius.
j. ulnar interosseus of index.
k. adductor pollicis.
l. abductor pollicis.
m. flexor brevis pollicis.

PLATE XIV.

Fig. 1. Muscles of front of forearm in *Macroglossus minimus*.

a. supinator longus.
b. pronator teres.
c. flexor carpi radialis.
d. flexor digitorum.
e. flexor carpi ulnaris.
f. abductor minimi digiti.
g. radial interosseus of minimus.
h. radial interosseus of annularis.
i. radial interosseus of medius.
j. ulnar interosseus of medius.
k. ulnar interosseus of index.
l. palmaris longus.

Fig. 2. Diagram of digital tendons in *Vampyrops vittatus*.

a. palmaris longus.
b. its radial tendon to pollex.
c. its ulnar tendon to pollex.
d. tendon to index.
e. tendon to medius.
f. tendon of flexor digitorum to pollex.
g. tendon of same to medius.
h. flexor digitorum.
i. annular ligament.

Fig. 3. Diagram of flexor tendons in *Macroglossus minimus*.

a. flexor carpi radialis.
b. its tendon to carpus.
c. its tendon to index.
d. palmaris longus.
e. its tendon to pollex.
f. its tendon to index.
g. flexor digitorum.
h. its tendon to pollex.
i. tendon to index.
j. tendon to interosseus of medius.
k. flexor carpi ulnaris.
l. its tendon to fourth metacarpal.
m. tendon to fifth metacarpal.
n. tendon to abductor minimi digiti.

Fig. 4. Tendons on back of wrist in *Cynonycteris amplexicaudatus*.

a. extensor carpi ulnaris.
b. extensor communis digitorum.
c. tendon to minimus.
d. tendon to annularis.
e. tendon to medius.
f. extensor ossis metacarpi pollicis.
g. extensor pollicis longus.
h. extensor pollicis et indicis.
i. extensor indicis.
j. extensores carpi radiales.
k. tendon of brevior.
l. tendon of longior.

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Fig. 5. Antebrachial muscles of *Noctulina altivolans*.

a. biceps tendon.
b. humero-cutaneus.
c. supinator longus.
d. pronator teres.
e. flexor digitorum.
f. flexor carpi ulnaris.
g. abductor pollicis.
h. flexor brevis pollicis.
i. opponens indicis.
j. two interossei of medius.
k. interosseus of annularis.
l. interosseus of minimus.

Fig. 6. Deep abdominal muscles of *Megaderma lyra*.

a. psoas parvus.
b. posas magnus.
c. quadratus lumborum.
d. obturator externus.
e. pectineus, origin of.
f. caudo-femoralis.
g. extensor cruris.
h. diaphragm.

Fig. 7. Muscles of the thigh in *Macroglossus minimus*.

a, *b*, *c* as in fig. 6.
d. iliacus.
e. gracilis.
f. hamstrings.
g. rectus femoris.

Fig. 8. Muscles of the thigh in *Macroglossus minimus*.

a, *b*, *d*, *g* as in fig. 7.
f. semimembranosus.
h. semitendinosus.
i. pectineus.
j. adductor brevis.
k. adductor magnus.

Fig. 9. Femoral muscles of *Macroglossus minimus*.

a, *b*, *d*, *g*, *k* as in fig. 8.
l. quadratus femoris.
m. obturator externus.

Fig. 10. Gluteal muscles of *Macroglossus minimus*.

a. gluteus medius.
b. iliacus.
c. gluteus quartus.
d. rectus femoris.
e. caudo-femoralis superior.
f. ditto inferior.
g. semitendinosus.
h. semimembranosus.
i. dorsum ilii.
j. sacro-sciatic foramen.
k. tuber ischii.

Fig. 11. Anterior femoral muscles of *Cephalotes Pallasii*.

a. iliacus.
b. psoas magnus.
c. psoas parvus.
d, *d'*. gracilis.
e. rectus femoris.
f. adductor magnus.
g. adductor brevis.
h. slip from pectineal point to the insertion of the gracilis; perhaps a sartorius?
i. pectineus.
j. semimembranosus.
k. semitendinosus.

Fig. 12. Thigh-muscles of *Noctulina altivolans*.

a. gracilis.
b. pectineus.
c, *e*. iliacus.
f. pectineus.

d, g. rectus femoris.
h. quadratus femoris.
i. adductor brevis.
i. semimembranosus.
j. semitendinosus.

Fig. 13. Extensor aspect of femur of *Macroglossus minimus.*

a. dorsum of ilium.
b. iliacus.
c. pyriformis.
d. rectus femoris.
e. femoral head of the extensor cruris (cruræus and vasti in one).

Fig. 14. Gluteal and other muscles of *Noctulina altivolans.*

a. gluteus medius.
b. iliacus.
c. rectus femoris.
d. femoral head of extensor cruris.
e. caudo-femoralis.
f. semitendinosus.
g. semimembranosus.
h. gluteus maximus.
i. belly of extensor cruris.
j. gastrocnemius.
k. flexor digitorum longus.
l. peronæi muscles.
m. elevator of the styliform bone.
n. depressor of the styliform bone.
o. extensor brevis digitorum.
p. peroneal tendon.

Fig. 15. Gluteal muscles of *Macroglossus minimus.*

a. gluteus maximus.
b. iliacus.
c. semitendinosus.
d. semimembranosus.

Fig. 16. Crural muscles of *Vampyrops vittatus.*

a. gastrocnemius.
b. fibular head.
c. tibial head with sesamoid bone.
d. flexor digitorum longus.
e. flexor hallucis longus.
f. depressor of the styliform bone.
g. flexor brevis digitorum.

Fig. 17. Crural muscles of *Vampyrops vittatus,* deep flexors.

a. flexor tibialis digitorum.
b. popliteus, rudimental.
c. flexor hallucis longus.
d. tibialis posticus.
e. tendon of tibialis posticus.
g. depressor of the styliform bone.
h. tendon of the flexor hallucis.
i. abductor minimi digiti.
j. tibial lumbricalis of minimus.
k. fibular lumbricalis of annularis.
l. tibial lumbricalis of annularis.
m. tibial lumbricalis of medius.
n. fibular lumbricalis of index.
o. abductor hallucis.

Fig. 18. Diagram of flexor tendons and lumbricalis in *Vampyrops.*

a. flexor digitorum.
b. flexor hallucis.
c. flexor hallucis brevis.
d. tendon of fl. digitorum to hallux.
e. tendon of same to index.
f. tendon of same to medius.
g. tendon of same to annularis.
h. tendon of same to minimus.
i. fibular lumbricalis of minimus.
j. tendon of flexor hallucis for annularis.
k. ditto for medius.
l. ditto for index.
m. ditto for hallux.
n. fibular lumbricalis for annularis.
o. tibial lumbricalis for annularis.
p. fibular lumbricalis for medius.

Fig. 1.

Fig. 2.

W. H. Wesley lith.

W. West & Co imp.

q. tibial ditto.
r. fibular lumbricalis for index.
s. tibial ditto.
t. continuation of ditto.
u. tendons to minimus.
v. tendons to annularis.
w. tendons to medius.
x. tendons to index.
y. tendons to pollex.

Fig. 19. Plantar muscles of *Macroglossus minimus*.

a. tibia.
b. fibula.
c. os calcis.
d. cuboid bone.
e. abductor ossis metatarsi minimi digiti.
f. abductor minimi digiti.
g. transversus pedis posterior.
h. transversus anterior.
i. abductor hallucis.
j. flexor brevis hallucis.
k. rudimental opponens.
l. tibial interosseus of index.
m. fibular of ditto.
n. tibial of medius.
o. fibular of ditto.
p. tibial of annularis.
q. fibular of ditto.
r. tibial of minimus.

PLATE XV.

Fig. 1. Body-muscles of *Cephalotes Pallasii*, front view.

a. frontalis.
b. procerus nasi.
c. nasal head of levator labii superioris.
d. angular head of ditto.
e. levator anguli oris.
f. orbicularis palpebrarum.
g. zygomaticus minor.
h. auriculo-angularis.
i. attrahens aurem.
j. masseter.
k. attollens aurem.
l. sterno-mastoid, superficial.
m. sterno-mastoid, deep layer.
n. cleido-mastoid.
o. splenius.
p. sterno-hyoid.
q. occipito-pollicalis.
r. omo-hyoid.
s. pectoralis major.
t. subclavius.
u. serratus anticus.
v. pectoralis quartus.
w. subscapularis.
x. biceps flexor cubiti.
y. triceps extensor.
z. coraco-brachialis.
α. serratus magnus.
β. external oblique.
γ. rectus abdominis.
δ. internal oblique.
ϵ. iliacus.
ζ. rectus femoris.
η. pectineus.
θ. hamstrings.
ι. adductor brevis.
κ. epicoracoid.
λ. hypogastric muscular deficiency above the pubes and between the recti.

Fig. 2. Body-muscles of *Cephalotes Pallasii*, back view.

a. occipitalis.
b. retrahens aurem.
c. occipito-pollicalis.
d. splenius.
e. slip from occipito-pollicalis to retrahens aurem.
f. nuchal accessory slip to occipito-pollicalis.
g. levator claviculæ.
h. levator anguli scapulæ.
i. supraspinatus.
j. rhomboideus.
k. serratus magnus.
l. deltoideus acromialis.
m. deltoideus scapularis.
n. teres major.
o. triceps.
p. biceps.
q. latissimus dorsi.
r. erectores spinæ.
s. gluteus maximus.

PLATE XVI.

Fig. 1. Cutaneous muscles of *Pteromys volans*.

a. transversus nuchæ.
b, *c.* jugo-pollicalis.
d. pectoralis major.
e. styliform bone of carpus.
f. carpo-tarsalis.
g. carpopatagialis.
h. coracopatagial fibres.
i. coraconotal.
k. ilio-cutaneus.

Fig. 2. Cutaneous neck-muscles of *Pteromys*.

a. origin of jugo-pollicalis.
b. jugo-pollicalis.
c. transversus nuchæ.

Fig. 3. Superficial thigh-muscles of *Galeopithecus volitans*.

a. reflected integument.
b. external oblique of abdomen.
c. iliac crest.
e. sartorius.
f. iliacus.
g. rectus.

Fig. 4. Thigh-muscles of *Pteromys*, back view.

a. tensor vaginæ femoris.
b. gluteus maximus.
c. rectus and vastus externus.
d. agitator caudæ.
e. caudal origin of semitendinosus.
f. bicipiti accessorius.
g. biceps.
h. gastrocnemius externus.

Fig. 5. Thigh-muscles of *Pteromys*, front view.

a. iliacus.
b. psoas magnus.
c. psoas parvus tendon.
d. tensor vaginæ femoris.
e. vastus internus.
f. adductor brevis.
g. condyloid part of the adductor magnus.
h. semimembranosus.
i. gracilis.
j. semitendinosus, ischiatic head.
k. caudal origin.
l. rectus femoris.
m. edge of adductor longus.
n. pectineus.

Fig. 1.

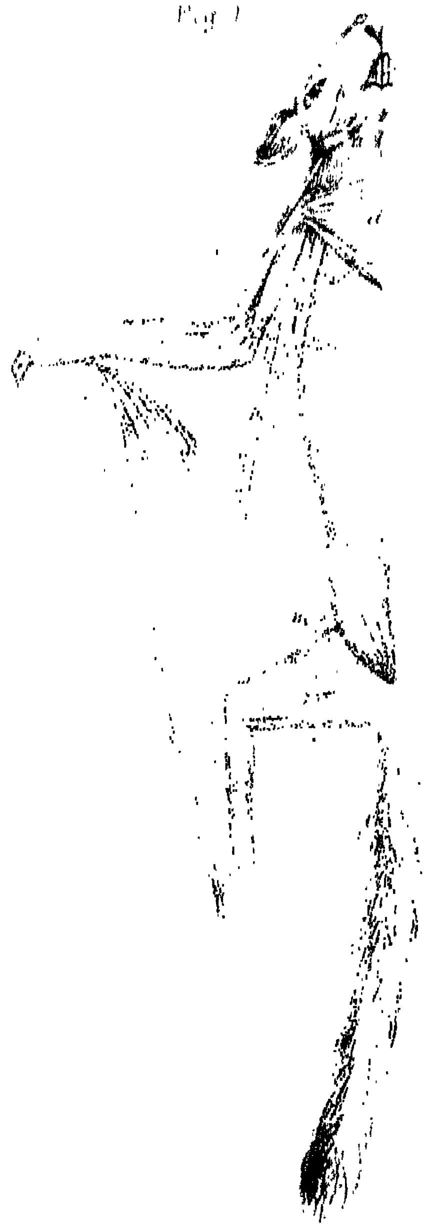


Fig. 3.

Fig. 5.

Fig. 6.

Fig. 4.

Fig. 2.

Fig. 7.

W. H. Wesley lith.

W. West & Co. imp.

Fig. 6. Posterior shoulder-muscles of *Pteromys*.

a. supraspinatus.
b. occipital rhomboid.
c. scapular deltoid.
d. acromion deltoid.
e. triceps externus.
f. triceps longus.
g. dorsi epitrochlear.
h. teres major.
i. latissimus dorsi.
j. brachialis anticus.
k. biceps.
l. supinator longus.
m. muscles from external condyle.

Fig. 7. Internal surface of arm-muscles of the same.

a. pectoralis minor.
b. subscapularis.
c. dorsi epitrochlear.
d. triceps longus.
e. triceps internus.
f. coraco-brachialis longus.
g. coracoid head of biceps.
h. long head of biceps.
i. coraco-brachialis brevis.
j. insertion of great pectoral.

IX. *On the Fossil Mammals of Australia.*—Part VI. Genus *Phascolomys*, GEOFFR. *By Professor* OWEN, *F.R.S. &c.*

Received September 14,—Read December 7, 1871.

§ 1. *Introduction.*—In a paper "On the Osteology of the Marsupialia"* I noted the expansion of the base of the nasal bones in the genus *Phascolomys*, and the agreement of the Wombat in this character with the Koala, Phalangers, Petaurists, Myrmecobians, Dasyures, and Opossums; thus indicating, as far as observation then warranted, a general marsupial character of form in those bones.

In a second paper I entered upon a comparison of the nasal bones in *Phascolomys vombatus*, Geoff., and *Phasc. latifrons*, Owen, and showed that, in the latter species, "the nasal bones were relatively broader, forming the whole upper surface of the anterior third of the skull"†.

In the 'Descriptive Catalogue of the Osteological Series in the Museum of the Royal College of Surgeons of England,' another character was pointed out in "the superior breadth of the part of the maxillary ascending in front of the malar and lacrymal bones to join the nasals" in *Phascolomys latifrons.* "The greater relative breadth of the nasal bones, as compared with those of *Phascolomys vombatus*," was also noted among the characters differentiating a third species of existing Wombat defined in that work‡ as *Phascolomys platyrhinus.*

§ 2. *Nasal bones in* Phascolomys vombatus, *Pér.*—I now proceed to consider, as far as materials permit, the amount of variety to which the same species of Wombat may be subject in the nasal bones,—a requisite preliminary to determining the value of these bones in differentiating recent and fossil species of *Phascolomys.*

In an old male Tasmanian Wombat (*Phasc. vombatus*) the basal breadth equals two thirds of the length of the pair of nasal bones§. The outer angles of the nasals, at their base ($_{15}$), are divided from the lacrymal tubercle ($_{73}$) by a strip of maxillary ($_{21}$) 4 lines in breadth, joining to that extent the frontal ($_{11}$). The sides of the pair of nasals converge forward at the hinder third, then run parallel, gently curving inward, and finally gaining the margin of the nostril, with a slight curve outward. Thus the course of each lateral border of the nasals is undulate. Their tips ($_{15'}$) extend forward

* Transactions of the Zoological Society, vol. ii. (1838) p. 387.

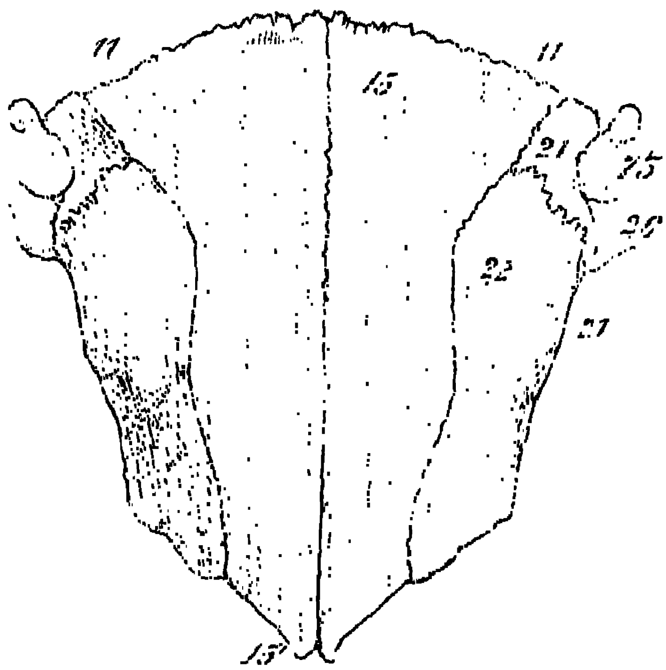
† Ib. vol. iii. (1845) p. 304, pl. xxxvii. figs. 1 & 4.

‡ 4to (1853), p. 334.

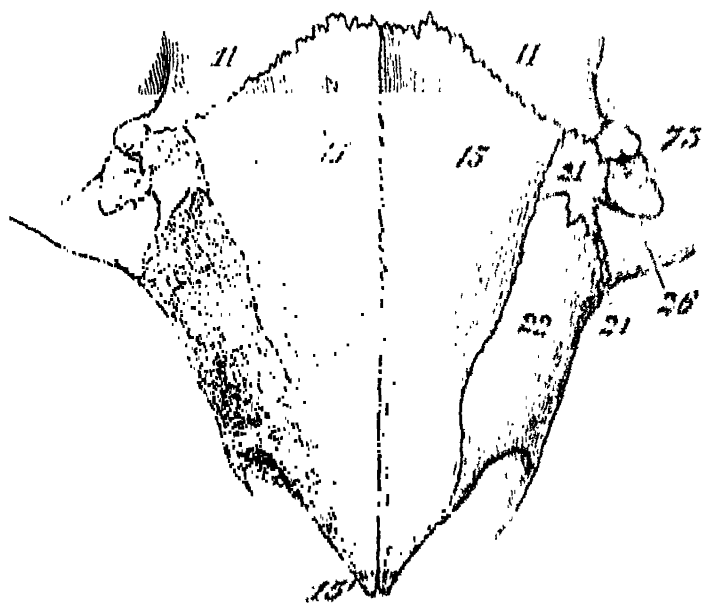
§ This proportion is expressed as follows by Dr. MURIE in describing his specimen of *Phascolomys vombatus*:—"The proportional breadth of the two nasal bones at their hinder ends is to their length as 68 to 100." (Proc. Zool. Soc. 1867, p. 802.)

about three lines in advance of the naso-premaxillary suture, and are bevelled off to an obtuse point from without obliquely inward and forward. Together these bones form the middle third of the upper border of the external bony nostril. The frontals (11) make a slight projection into the middle of the fronto-nasal suture, which from this shallow indent runs outward and a little forward to the nasal process of the maxillary (21)*. The naso-maxillary suture forms the hind fifth part of the lateral border of the nasals; the naso-premaxillary suture runs along the rest of the extent of the nasal bones; *i. e.* to the beginning of their free ends, which are short and subobtuse.

Fig. 1.



Nasal bones and their connexions, var. 2, *Phascolomys vombatus*, Geoffr.



Nasal bones and their connexions, var. 3, *Phascolomys vombatus*, Geoffr.

In a second Tasmanian Wombat the nasals (fig. 1, 15) differ from those above described in their basal breadth, this being equal to rather more than three fourths of their length, or as 77 to 100, also in the absence of any mesial indent of the fronto-nasal suture, and in the sharper convergence forward of the hinder fourth part of the lateral margins. These margins describe a similar wavy course, convex outwards along the middle third, or a little in advance of it. The apices overhanging the nostril are less sharp and prominent than in the last or type specimen.

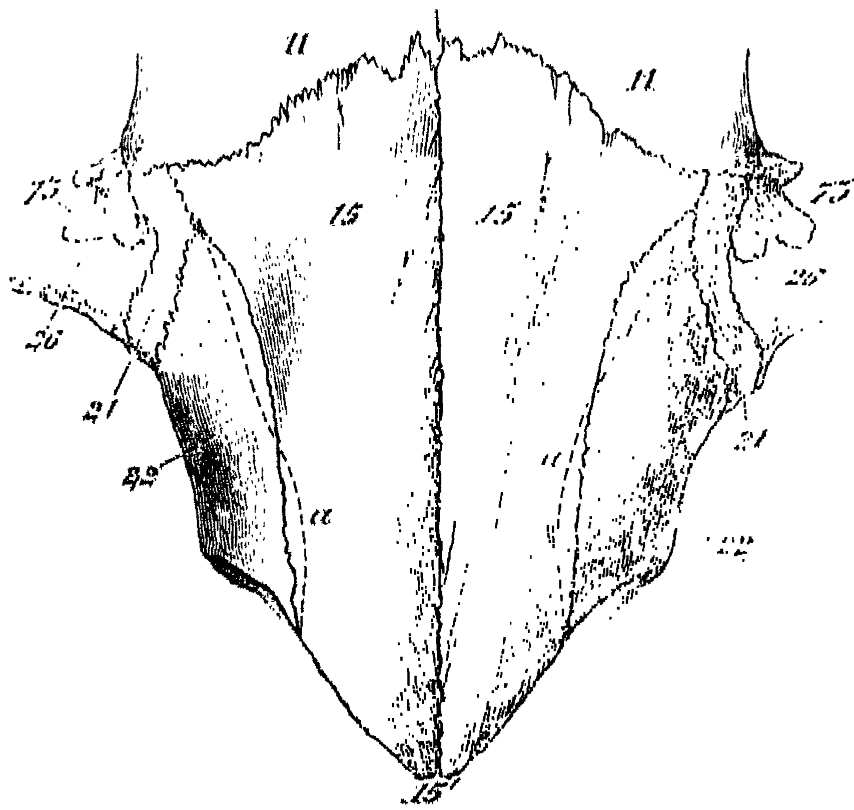
In a third younger *Phascolomys vombatus* (fig. 2) the lateral margins converge more gradually and in an almost straight line from the base to the anterior fourth of the nasals, where the margins extend nearly straight to the nostril. The middle sixth part of the fronto-nasal suture is slightly concave; the rest extends outward and more obliquely forward than in the two preceding specimens. The apices of the nasals projecting beyond the premaxillo-nasal sutures are sharp, and form one fifth the length

* This specimen, figured in my first paper (*loc. cit.*), shows the usual characters and is not here figured: the references to the numerical symbols of the bones, in aid of the description, are seen in the subjects of the two Woodcuts showing the varieties.

of the whole lateral margin of the bone. The basal breadth bears almost the same proportion to the length of the nasals as in the first cited skull.

§ 3. *Nasal bones in* Phascolomys platyrhinus, *Ow.*—The Platyrhine Wombat, in the absence of postorbital processes, the shortness of the naso-maxillary suture, and the deep emargination of the fore part of the nasal process of the premaxillary, is more nearly allied to *Phasc. vombatus* than either of these species are to *Phasc. latifrons**; but the nasal bones (fig. 3, $_{15}$) are relatively broader in the Platyrhine than the Tasmanian

Fig. 3.



Nasal bones and their connexions, *Phascolomys platyrhinus*, Ow.

Wombat, the outer basal angles approaching as near to the lacrymal tubercles (ib. $_{73}$) with a greater relative breadth of the skull at that part. In one skull the lateral borders of the nasals have the same undulatory course, but more feebly marked than in the second variety of *Phasc. vombatus* (fig. 1). In a second the suture between the nasals ($_{15}$) and premaxillaries ($_{22}$) runs as in fig. 3. There is a narrow and irregular intrusion of the frontal at the middle of the fronto-nasal suture, sometimes at the expense of the right (as in fig. 3), sometimes of the left nasal bone. The breadth of the base of both bones equals five sevenths of the length of the nasals in two specimens, and four fifths in a third. The apices ($_{15'}$), projecting anterior to the naso-premaxillary suture ($_{22'}$), are blunter than in the first variety of *Phascolomys vombatus*. The width or breadth of the nasals, at their base or fronto-nasal suture, begins to diminish at once, as they advance, by the converging course of the naso-maxillary ($_{15-21}$) and naso-pre-

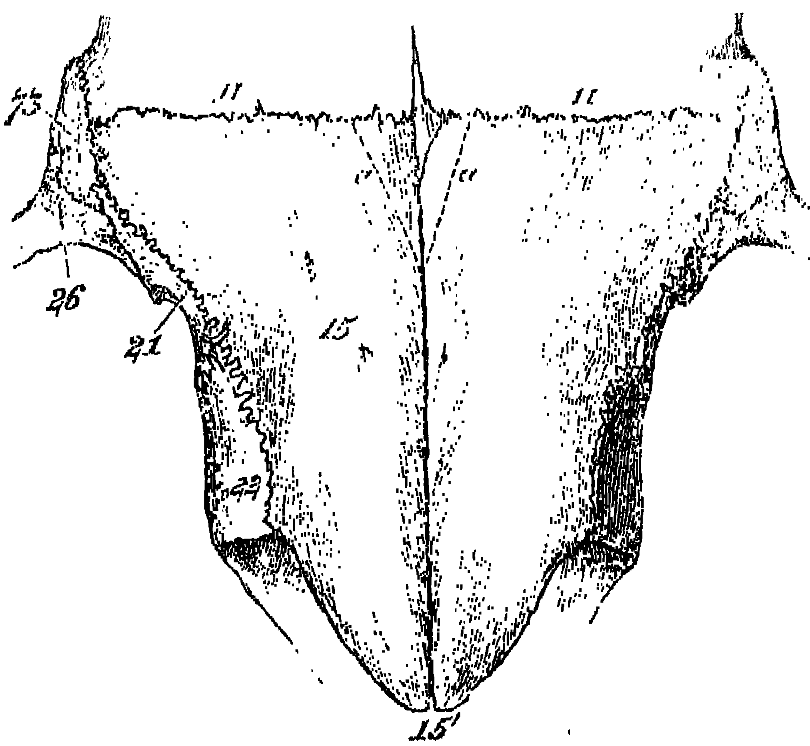
* This relation is pointed out by Dr. Murie, who remarks:—"*Phascolomys latifrons* shears off from the common form of Wombat and reverts to the true marsupial type in several particulars" (*loc. cit.* p. 800). These, however, he does not cite; and I may have to note some points in which it seems rather to diverge from the common character.

maxillary ($_{15-22}$) sutures. In not any of the three specimens before me is "the width of the nasals continued forward beyond their middles"*. In one variety the course of the naso-premaxillary suture was such as is shown by the dotted line *a a* in figure 3. A broader strip of the maxillary ($_{21}$) divides the malar ($_{26}$) from the premaxillary ($_{22}$) in the present species than in *Phascolomys vombatus*. This is a good and constant character in a comparison of the two species.

§ 4. *Nasal bones in* Phascolomys latifrons, *Ow.*—The breadth of the fore part of the frontals in the Latifront or Hairy-nosed Wombat is made to contrast with the narrowness of the rest of the bones by the outward extension of the postorbital processes†; the nasals (fig. 4, $_{15}$) present a more regular triangular form, through the prevailing transverse course of the fronto-nasal suture ($_{11-15}$) and the more regular convergence of the lateral margins of the nasals to the fore ends of the naso-premaxillary sutures ($_{15}$ $_{22}$). Beyond these the lateral margins of the nasals converge more rapidly to their apices ($_{15'}$), which extend freely further forward than in the two preceding species. The breadth of the nasals at the base of their free extremities is greater than in the bare-nosed Wombats, and the upper surface of the entire bones is flatter.

In one of the two skulls before me of *Phascolomys latifrons* the left frontal breaks the transverse course of the fronto-nasal suture by a sharp-pointed process or wedge between the two nasals (indicated by the upper line in fig. 4); in the second skull

Fig. 4.



Nasal bones and their connexions, *Phascolomys latifrons*, Ow.

the right frontal sends forward in the same way a more obtuse triangular process; in my type skull (Zool. Trans. vol. iii. pl. xxxvii. fig. 4) both frontals contribute equal shares to the wedge, which is longer (as shown by the lower dotted lines, *a*, *a*, in fig. 4).

* MURIE, *loc. cit.* p. 803.

† Plate xxxvii. fig. 4, *o*, *o*, Zool. Trans. vol. iii. (1845) (nat. size); also MURIE, Proceedings of the Zool. Soc. 1865, p. 844, fig. 1 (half nat. size).

Outside this, in all Latifront Wombats, the fronto-nasal suture runs straight outward to the lacrymal ($_{73}$), from which bone it is not separated, as in *Phascolomys platyrhinus* and *Phasc. vombatus*, by the maxillary ($_{21}$). The extent of the naso-maxillary suture ($_{15-21}$) equals that of the naso-premaxillary suture ($_{15-22}$).

These differences in the connexions of the nasals are more significant of specific distinction than the shape of the bones. The naso-maxillo-premaxillary suture ($_{15-21-22}$) is very slightly concave outwardly in the Latifront Wombat; and the free border of the nasals beyond the suture affects a convex bend toward the apices.

§ 5. *Nasal bones in* Phascolomys Mitchelli, *Ow.*—There would be no doubt in determining *Phascolomys latifrons* by the naso-maxillo-premaxillary part of the skull, at least as being distinct from the other two known recent species, if even the still more characteristic part of the frontal bones was wanting. There might be more difficulty in pronouncing as to whether a fore part of the skull belonged to *Phascolomys platyrhinus* or to *Phasc. vombatus*.

I now proceed to compare such a fragment of a fossil skull of a Wombat on the basis of the characters which comparisons of different individuals of the three well-determined recent species of *Phascolomys* affords.

The fragment in question (Plate XVII. figs. 1, 3, 4, 5) includes the nasals ($_{15}$) with parts of the frontals ($_{11}$), lacrymals ($_{73}$), malars ($_{26}$), maxillaries ($_{21}$), premaxillaries ($_{22}$), and palatines ($_{20}$). The nasals ($_{15}$) are of the type of those in *Phascolomys vombatus* and *Phascolomys platyrhinus*; in the proportion of basal breadth to length and the speedy narrowing as they advance they resemble the modification shown in Woodcut, fig. 1, p. 174, in *Phasc. vombatus*. But small as is the extent of the naso-maxillary suture ($_{15-21}$) in *Phasc. vombatus* (figs. 1 & 2) and *Phasc. platyrhinus* (fig. 3), it is still less in the fossil, the apex only of the basal expanse of each nasal ($_{15}$) touching the maxillary ($_{21}$) (Plate XVII. fig. 1) on each side of the skull. The naso-premaxillary suture (ib. $_{15-22,\ 22'}$) runs along the side borders to within half an inch of the extremities ($_{15'}$), which are obtusely pointed, as in *Phascolomys platyrhinus*. The suture or lateral border of the nasals describes but two curves, concave at the basal half, convex at the apical one; slight in both, in *Phascolomys Mitchelli*. The angle formed by the fronto-nasal suture ($_{11-15}$) is as in *Phasc. platyrhinus* (fig. 3); and an obtuse process, 3 lines broad, of the frontal is wedged into the beginning of the internasal suture.

Seeing the variations in regard to such frontal wedge, as in the sinuous course of the lateral borders of the nasal, these bones could not differentiate by their form the fossil from the existing continental Wombat (*Phasc. platyrhinus*). The superiority of size is but small in the fossil; but the difference of connexion, shown in the almost exclusion of the maxillary from junction with the nasal, is a satisfactory distinctive characteristic of this part of the skull of the fossil Wombat under consideration, which I refer to the *Phascolomys Mitchelli*, Ow.*

* First defined in Appendix to MITCHELL'S 'Three Expeditions into the Interior of Eastern Australia,' vol. ii. 8vo, 1838, pl. 48. figs. 4–7, p. 368 (2nd ed.).

The present representative of that species is from the same bone-cave as the type fossils*; it has been flattened or crushed from above vertically downwards. The facial parts of the premaxillaries (22, 22') are on the same horizontal plane as the nasals (15), which they suturally join. The frontals (11, 11) have been pressed away from the nasals along the major part of the suture, and all the bones are more or less fractured. To this condition the skull had been reduced before the drip of the cavern had hardened the red mud about it. The process of clearing away such matrix was long and tedious.

Did the skull show the violence of a carnivorous troglodyte destroyer, or the effect of some cosmical force operating on the breccia-bed of the cave? If the former, the blunted laniaries of our old *Thylacoleo* are the only animal dynamic in Australia capable of so smashing the Wombat's head that I am as yet cognizant of.

§ 6. *Nasal bones in* Phascolomys Krefftii, Ow.—This species is founded on a fore part of a skull (Plate XVII. figs. 2, 6) discovered by GERARD KREFFT, Esq., in the same bone-cave as the last-described fossil. It is as closely allied to the broad-fronted or hairy-nosed Wombat as *Phascolomys Mitchelli* is to the bare-nosed continental species; and the value of the nasal characters comes well out in the comparisons determining the present fossil.

It includes the major part of the nasals (15), with the connected parts of the premaxillaries (22) and maxillaries (21). The nasals are broad and flat; their lateral margins are suturally joined with a smaller proportion of the premaxillaries than in *Phascolomys latifrons* (Woodcut, fig. 4, 22).

The free anterior extremities of the nasals (15') show nearly the same form and proportions as in that Woodcut; their basal breadth, where the naso-premaxillary suture ends anteriorly, is 1 inch 3 lines; the length of the outer margin is 1 inch in a straight line, but is rather more following the curve. The lateral suture, as it extends along the maxillary (21), shows a slight uniform curve, concave outward. A portion of the left fronto-nasal suture (11–15) indicates an oblique course from within outward and forward in about the same degree as in *Phascolomys platyrhinus*, fig. 3. I have not seen such course, as a variety, of that suture in any specimen or figure of the skull of the recent *Phascolomys latifrons.* Other instances of combination in the smaller fossil Wombats, such as are now under review, of characters which respectively specialize the Platyrhine and Latifront Wombats will be adduced in the present memoir.

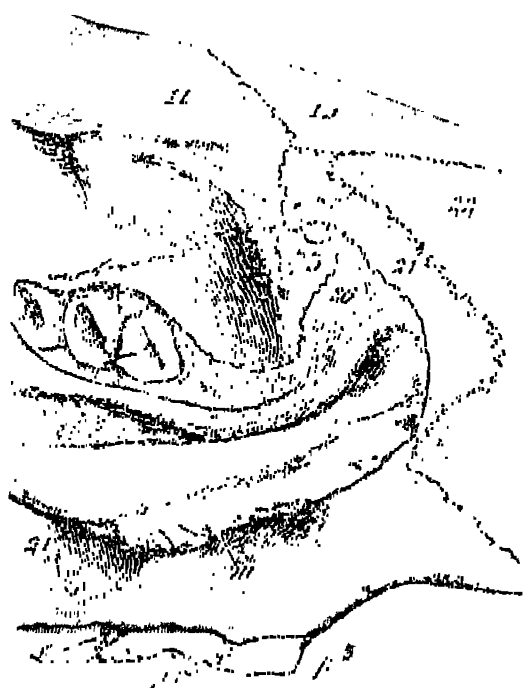
The length of the left nasal, as far as it is indicated by the preserved extent of its suture with the frontal, is 2 inches 10 lines; the extreme basal breadth cannot be given, on account of the side-fractures.

The internasal suture seems to be partially obliterated; and there is a narrow elliptical vacuity with rounded margins, situated ten lines from the tips of the nasals, six lines in length and two lines in extreme breadth, which seems to be natural, though probably an individual variety. I shall return again to this fossil in relation to other characters.

* MITCHELL'S 'Three Expeditions into the Interior of Eastern Australia,' vol. ii. 8vo, 1838, pl. 48. figs. 4–7.

§ 7. *Lacrymal, maxillary, and palatal characters of* Phascolomys Mitchelli, *Ow.*—So much of the lacrymal ($_{73}$) is fortunately preserved on the right side of the subject of Plate XVII. fig. 3, *t*, as to indicate the affinity of the fossil to certain existing Wombats. This bone, both in *Phascolomys vombatus** and *Phasc. platyrhinus* (Woodcut, fig. 5), developes a prominent tubercle above $_{73}$ at its upper border, below the fronto-maxillary suture ($_{11-21}$). In *Phascolomys latifrons* (fig. 6) a feeble swelling of the lacrymal ($_{73}$), where it

Fig. 5.



Lacrymal &c. characters, *Phascolomys platyrhinus.*

Fig. 6.

Lacrymal &c. characters, *Phascolomys latifrons.*

joins the frontal ($_{11}$), answers to the tubercle. The indications of a lacrymal canal are minute in all Wombats. The lacrymal of *Phasc. Mitchelli* (Plate XVII. fig. 3, $_{73}$) shows the well-developed tubercle (*t*) in the same relative position to the fronto-maxillary suture as in *Phascolomys vombatus* and *Phasc. platyrhinus*: the bone anterior to the tubercle is flatter, less excavated in *Phasc. Mitchelli* than in those existing Wombats, and herein more resembles the lacrymal in *Phascolomys latifrons.*

The alveoli of the five upper molars of each side (Plate XVII. fig. 5, *p* $_{3, 4}$, *m* $_{1, 2, 3}$) with the intervening part of the bony palate (ib. $_{20, 21}$) are preserved in the present fossil. The form of the latter adheres to the type of that of *Phascolomys vombatus*† and *Phasc. platyrhinus* (Woodcut, fig. 7); in *Phasc. latifrons* (Woodcut, fig. 8) the palate ($_{20, 21}$) is less contracted anteriorly. The fore part of the postpalatal apertures (Plate XVII. fig. 5, *b*) does not reach that of the hindmost socket (*m* $_{3}$) in the fossil, which also in this respect agrees with *Phascolomys vombatus*‡ and *Phasc. platyrhinus* (Woodcut, fig. 7, *b*); whilst it

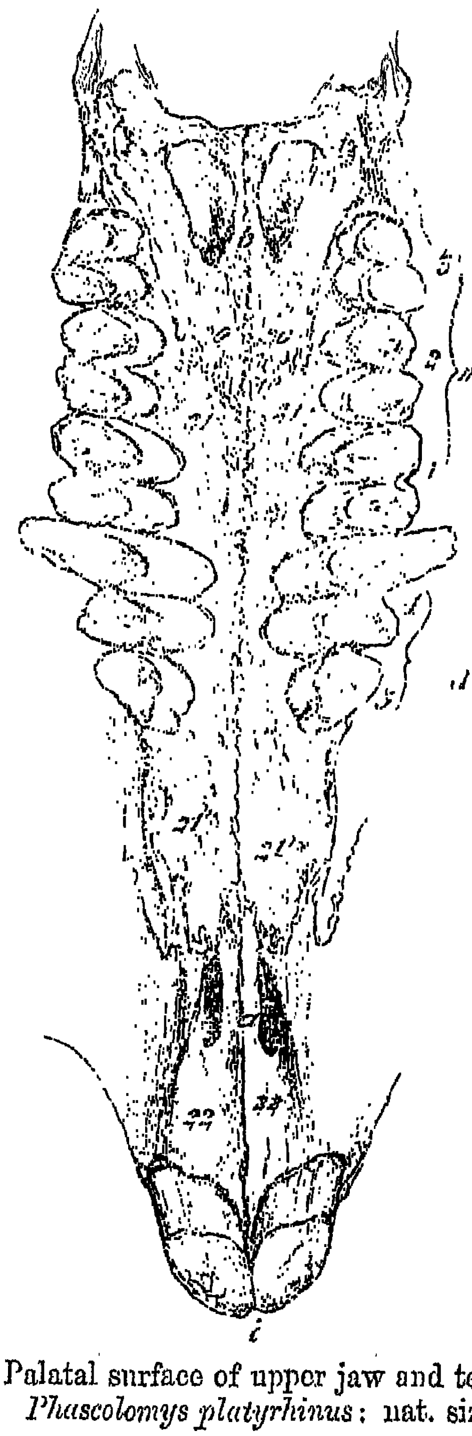
* Trans. Zool. Soc. vol. iii. pl. xxxvii. figs. 1 & 2. It is also represented in figs. 2 & 3 of Dr. Murie's memoir *loc. cit.* p. 814, but the suture dividing the tubercular lacrymal from the frontal is not marked.

† Trans. Zool. Soc. vol. ii. plate lxxi. fig. 1.

‡ Ibid.

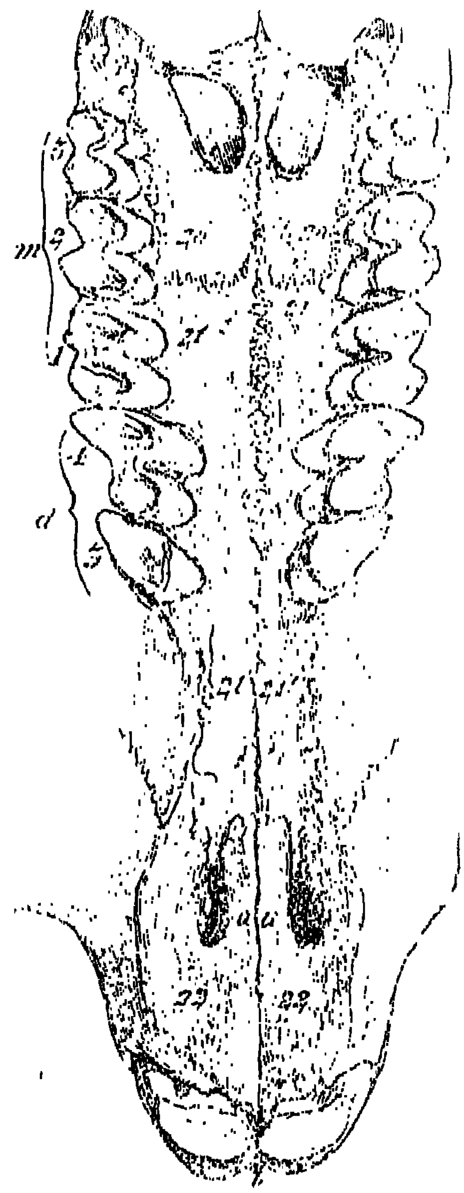
differs from *Phascolomys latifrons* (Woodcut, fig. 8, *b*), in which the postpalatal apertures extend forward beyond, or at least as far as, the interval between the last and penultimate sockets*. In the more advanced portion of the roof of the mouth I noticed (in 1845) a character† in *Phascolomys latifrons* by which it differed from *Phasc. vombatus*, and as I now know it also differs from *Phasc. platyrhinus*. The portion of bony palate

Fig. 7.



Palatal surface of upper jaw and teeth,
Phascolomys platyrhinus: nat. size.

Fig. 8.



Palatal surface of upper jaw and teeth,
Phascolomys latifrons: nat. size.

between the molary series and the incisors is more concave transversely, or deeper, in *Phascolomys latifrons* (Woodcut, fig. 8, 21, 21′, 22, 22), and the channel is bounded by well-defined or sharp borders: this character is much better marked in the fossil (Plate XVII. fig. 5, 21′, 21′, 22, 22) than in the skulls of *Phascolomys vombatus* or *Phasc. platyrhinus*.

Another character in which the fossil resembles *Phascolomys latifrons* more than it

* In the latter variety (fig. 8) the apertures should extend more forward than is represented.

† Trans. Zool. Soc. vol. ii. plate lxxi. fig. 1. "The palatal surface of the intermaxillaries is deeper" (p. 304).

does the other two recent species is the greater vertical extent of the maxillary (Plate XVII. figs. 3 & 4, 21*) beneath the origin of the malar or zygomatic process (21*) of that bone (compare with Cuts 5 & 6, 21*). I shall recur to this character in the description of another fossil of the present genus.

§ 8. *Upper molars of* Phascolomys Mitchelli, *Ow.*—The differential characters of these teeth, as compared with their homologues in *Phascolomys vombatus*, have been elsewhere pointed out†. As to the two larger existing species, in the molar dentition of the upper jaw *Phascolomys Mitchelli* more resembles the platyrhine than the broad-fronted Wombat. In the latter the right and left upper molar series (Woodcut, fig. 8, *d* 3–*m* 3) run more parallel to each other, are less convergent anteriorly, with absolute greater breadth of the bony palate there. The first molar (*d* 3) in *Phascolomys latifrons* is, relatively to the second, larger in both upper and under jaws‡. I therefore limit the comparison of the upper molars in the present fossil to those of *Phascolomys platyrhinus* (fig. 7, *d* 3–*m* 3). The extent of the five alveoli, lengthwise, taken at their outlets, is the same in both; or at least the fossil (Plate XVII. fig. 5, *d* 3–*m* 3) exceeds only by about a line, giving 2 inches 2½ lines instead of 2 inches 1 line as in *Phascolomys platyrhinus*. I have seen no example of *Phascolomys latifrons* in which the molar series extended beyond 2 inches; it is commonly less, as in Woodcut, fig. 8.

The alveolus of the first molar (*d* 3) of the fossil indicates a tooth not larger than in the Platyrhine Wombat. The other four molars, of which the first three are preserved on the left side and the last two on the right side, closely repeat the characters of these teeth in the Platyrhine Wombat§. This gives more weight to the differential characters of greater length and less breadth of the nasals, the greater concavity and sharper definition of the diastemal part of the bony palate, and the greater depth of the maxillary below the anterior pier of the zygomatic arch in *Phascolomys Mitchelli*.

§ 9. *Palatine foramina in* Phascolomys.—I next proceed to notice Phascolomydian fossils from the freshwater deposits of Queensland, in the interpretation of which some observations must be premised on the palatal foramina in existing species of Wombat.

In my first paper on the Osteology of the *Marsupialia* I state that *Phascolomys* resembles *Phascolarctos* and *Hypsiprymnus* in having "the posterior palatal openings large and situated entirely in the palatal bones; and that posterior and external to these are two small perforations" ‖. In the other two species (*Phascolomys latifrons* and *Phascolomys platyrhinus*) determined by cranial characters since the date of that remark (1838), the generic characters of the postpalatal openings are repeated. These additional materials serve to test the statement that in Marsupials "the perforations of the bony palate

† MITCHELL's 'Three Expeditions into the Interior of Eastern Australia,' vol. ii. p. 368, pl. 48. See also WATERHOUSE, 'Natural History of the Mammalia,' 8vo, 1845, p. 244.

‡ *Loc. cit.* p. 304.

§ The second molar is abnormally worn, through slight displacement of the opposing tooth, as happens in other partially enamelled teeth of perpetual growth.

‖ "On the Osteology of the Marsupialia," Trans. Zool. Soc. vol. ii. p. 389.

deserve particular attention; they are generally specific, and of consequence in the determination of recent and fossil species"†.

In the skull of the Wombat from Tasmania (*Phasc. vombatus*), figured in the same Paper‡ to illustrate the palatal and other characters afforded by a basal view of the cranium, the foramina are oval, the base which is behind being rounded; but the small anterior end of the oval is so nearly pointed as to suggest the term "triangular." In two skulls since compared these foramina present the same shape and proportions; in two smaller and younger skulls of *Phasc. vombatus* they are relatively smaller, and rather elliptical than oval. In two skulls of *Phascolomys platyrhinus* in the Collection of the British Museum I note that the postpalatal foramina are longitudinally elliptical or oblong in one, and are triangular in the other; the larger continental bare-nosed species showing the same variety as the smaller Tasmanian Wombat. This, therefore, is an exception to the general rule of the specific value of the postpalatal character§. The larger, especially the longer postpalatal varieties, encroach more forward and come nearer to the transverse parallel of the anterior wall of the hindmost socket. Allowance must be made for this variation.

In two skulls of *Phascolomys latifrons* the postpalatine foramina are relatively larger, especially longer, than in either the Tasmanian or Platyrhine Wombats, and they are rounded anteriorly, but less broad there than behind.

Dr. Murie‖ notes the larger size of the postpalatine foramina in *Phasc. latifrons* as compared with *Phasc. platyrhinus*, and I therefore attach the more value to the character, as probably being more constant in the latifront species. It must, however, be considered in connexion with the more constant cranial characters. The following fragmentary fossil from the "breccia-cave" of Wellington Valley exemplifies the need of keeping this relation in view. The fossil consists of a left maxillary and palatine, with the molar alveoli, fractured at both ends (Plate XVII. figs. 7, 8); the anterior fracture exposes the socket of the first molar, d_3. By the anterior contraction of the palate and by the size and proportions of the alveoli the fossil resembles *Phascolomys platyrhinus*; by the parallelism transverely of the fore part of the postpalatal aperture and the same part of the posterior alveolus, and by the height of the maxillary below the malar process of that bone (fig. 7, 21^*), it resembles *Phascolomys latifrons*. By the combination of both characters it proves its relationship to *Phascolomys Mitchelli*; as in that species the prezygomatic ridge is less prominent or definite, and is higher placed than in existing Wombats.

§ 10. *Palate and upper molars,* Phascolomys Mitchelli, *from freshwater deposits,*

† "On the Osteology of the Marsupialia," Trans. Zool. Soc. vol. ii. p. 388.

‡ Ib. plate lxxi. fig. 6.

§ The skull of the Wombat, from New South Wales, with "two large triangular holes in the end of the palate," was probably the only one in the British Museum Collection at the date of Dr. Gray's comparison of it with the smaller Tasmanian species, which he believed to be differentiated by the "two moderate-sized oblong holes in the hinder part of the palate." ("Some Observations on the skull of *Phascolomys vombatus*," by J. E. Gray, F.R.S., Proc. Zool. Soc. 1847, p. 41.)

‖ *Loc. cit.* p. 844.

Queensland.—In a heavy petrified fragment of skull (Plate XVIII. figs. 1–4)†, including the molary series, upper jaw, and their alveoli, with the bony palate from its hind border or bar (*a*) to 4 lines in advance of the molars ($_{21}$, $_{21}$), the palate, as compared with that of the last-described fossil (Plate XVII. fig. 5), is more concave transversely, and its concavity is divided by a sharp ridge, extending from the interpalatine ($_{20}$, $_{20}$) along the intermaxillary‡ palatal suture, as far forward as the second molar (d_4).

The upper molars have a somewhat zigzag arrangement: the second (Plate XVIII. fig. 1, d_4) extends more mesiad than the first (d_3) or the third (m_1), the hind lobe of the third more so than the fore lobe of the fourth (m_2), and the hind lobe of the fourth more so than the fore lobe of the last molar (m_3). This arrangement is also shown in the palatal view of the fossil of *Phascolomys Mitchelli* (Plate XVII. fig. 5), and by the alveoli in the more fragmentary fossil of the same species (fig. 8) of the same Plate. The same character is seen in a minor degree in the outer contour of the grinding-surfaces. The antero-external angle of one tooth projects more outwardly than the postero-external angle of the tooth in advance. This arrangement, a tendency to which has been noted in *Diprotodon* and *Nototherium*, is more marked in the Tasmanian and Platyrhine Wombats, as in MITCHELL's fossil, than in *Phascolomys latifrons*.

The intermolary bony palate in the present fossil (Plate XVIII. fig. 1), though exceeding in length by the antero-posterior diameter of the last molar tooth that of *Phascolomys latifrons* (Woodcut, fig. 8), is narrower anteriorly than in that species, without being so broad posteriorly. It further differs from both this, the Platyrhine (Woodcut, fig. 7) and the Tasmanian existing Wombats, in the smaller size of the post-palatal foramina (ib. *b*, *b*); they are absolutely smaller than in *Phascolomys vombatus*, although the fossil indicates an animal as large as the largest *Phascolomys platyrhinus*. These foramina are, unfortunately, not preserved in the two previously described fossils; but the anterior boundaries in the subject of fig. 5, Plate XVII. indicate a size or breadth of the foramina equal to those in either the Latifront or Platyrhine existing species.

The *antero-posterior extent of the molary alveoli, upper jaw, of the present fossil* is 2 inches 2½ lines, which is exactly that in the cave-fossil (Plate XVII. fig. 5) and in the largest Platyrhine Wombat. But the palate is narrower in the fossil by 1 line posteriorly, besides being deeper or more concave across, and divided by a mid ridge.

The differential character noticed in the preceding fossils is here repeated, viz. the greater depth of the outer alveolar plate of the maxillary (Plate XVIII. fig. 2, $_{21}$) below the zygomatic process (ib. $_{21*}$); it is 10½ lines in the present fossil, and the premasseteric ridge or tuberosity (ib. *m*), less defined or prominent than in existing Wombats, is correspondingly raised above the alveolar outlets.

The worn surfaces of the molar teeth are rather broader transversely than in *Phasco*

† This fossil was presented to the British Museum, in 1861, by GEORGE BENNETT, Esq., F.L.S. It is from a freshwater deposit, Darling Downs.

‡ I use the term to signify the suture between the maxillary bones, in a sense different from that in which it is sometimes applied, viz. to the "premaxillary bone."

lomys platyrhinus, and the inner ends of the two lobes are more sharply, or less obtusely, angular than is usual in that species. The difference both in this character and the breadth of the molars is also notable between the present and the first-described fossil; but seeing the influence direction and degree of attrition have upon the size and shape of the grinding-surface of the molars, the differences noted may be within the limits of that influence. In the subject of Woodcut, fig. 7, d_4 had been abnormally abraded.

The characteristic downbending of the hind part of the palatines, which forms a transverse bar (Plate XVIII. fig. 1, *a*) behind the postpalatal apertures (ib. *b*, *b*), perforated at each end from behind forwards by a smaller aperture in the recent Wombats, is repeated in this present instructive fossil (ib. fig. 4, *d*, *d*).

This evidence of *Phascolomys Mitchelli* (Plate XVIII. figs. 1–4), from freshwater deposits, resembles *Phasc. platyrhinus* in the depth and position of the antero-internal longitudinal groove of d_3, which tooth is wanting in the cave fossil, although the socket (ib. fig. 5, d_3) indicates the same position of the groove. In *Phascolomys latifrons* the fore part of d_3 (Woodcut, fig. 8) is less produced than in *Phasc. platyrhinus* and *Phasc. Mitchelli.*

A difference in the grinding-surface of the upper molars and in the intervening bony palate between the subjects of fig. 5, Plate XVII., and fig. 1, Plate XVIII. is appreciable; but, as above remarked, the one may be due to a phase of attrition; and, moreover, the outer side of the surface is slightly mutilated in fig. 5, Plate XVIII.; whilst the variety in regard to a rising along the mid palatal suture in the Platyrhine Wombats warns against founding a specific distinction thereon.

These characters are of the less consequence, since, where they are not preserved in a fossil, there may be others which allow of no such hesitation in regard to the specific distinction of the Wombats; as, *e. g.*, in the case of that to which the fragment of skull about to be described belongs (Plate XVIII. figs. 5, 6, 7). It is a portion of the left maxillary with the bony palate intervening between the left and right molary series, the left series being in place (ib. fig. 7), the right represented by the second molar and the alveoli of the two following teeth: the extent of the left molary series at their issue from the alveoli is 2 inches 2 lines.

The chief value of the present specimen is the character of the malar process of the maxillary (ib. fig. 5, $_{21}$), which is preserved with the beginning of the attached part of the malar (ib. ib. $_{26}$) on the left side, showing the malo-maxillary suture. To this help in the determination of fossils of the marsupial genus under consideration I was led by the following comparisons.

In the largest of three skulls of *Phascolomys vombatus* available for the purpose, the left upper molary series, taken as in the fossil, does not equal 2 inches; it falls short by nearly a line. In the specimen figured in my "Osteology of the Marsupialia"*, it is 1 inch 8 lines; in the next in size it is 1 inch 10 lines; in an evidently younger Wombat, with all the molars in place and use, the series is 1 inch 7 lines.

* Trans. Zool. Soc. vol. ii. (1838) plate lxxi. fig. 6.

These five ever-growing teeth gain in fore-and-aft as in transverse diameter, until the full size of the individual is attained; they grow with the growth of the skull, though in a minor ratio; and I have no evidence of their exceeding in size the teeth requiring the extent of alveoli noted in the largest of the cranial specimens of *Phasc. vombatus* before me.

Now in this, as in the second-sized skull, the lower border of the malar process of the maxillary bone is 6 lines above the margin of the outer wall of the alveolar opening of m_2; in the younger and smaller skull it is 5 lines. In all the specimens the maxillary contributes to the inner and lower part of the beginning, or anterior pier, of the zygoma, speedily narrowing to a point as it passes backward on the outer side of the arch, where it ends about 7 lines from the back part of the origin of the process; the depth or vertical diameter of the outer side of the base of the zygomatic process of the maxillary is about 2 lines.

In the skull of a *Phascolomys latifrons* with an upper molary series, taken at the alveolar outlets, of 1 inch 10 lines in extent, the malar process of the maxillary rises 7½ lines above the issue of the second molar, there contributes 3½ lines in depth to the under and fore part of the beginning of the zygoma, and narrows to a point 7 lines behind its origin. In another skull of *Phascolomys latifrons* with a molary series of 1 inch 1 line in extent, the maxillary process rises 8 lines above the outlet of the second molar, and contributes a similar small proportion to the under and fore part of the zygoma.

In the skull of a *Phascolomys platyrhinus* with a molary series 2 inches 1 line in extent, the malar process of the maxillary (Woodcut, fig. 5, $_{21*}$) rises 6 lines above the outlet of the second molar, and contributes 3½ lines to the vertical extent of the beginning of the zygoma ($_{26}$), which here has a total depth of 1 inch 4 lines; the process ($_{21*}$) decreases to a point at 9 lines from its origin.

In the fossil (Plate XVIII. fig. 5) with a molary series of the same extent as in the last skull, the malar process of the maxillary ($_{21}$) rises 9 lines above the outlet of the molar, and contributes 7 lines to the vertical extent of the fore part of the zygoma ($_{26}$). The different relation of the malo-maxillary suture to the premasseteric ridge (*m*) is strongly marked between the fossil and any of the recent species of Wombat, the interspace between the front pier of the zygomatic arch and the alveolar outlets being much greater in the fossil.

In the extent, especially hinder breadth and feeble concavity, of the bony palate, *Phascolomys platyrhinus* most resembles the present (ib. fig. 7) as it does the preceding fossil; but the zygomatic character only stands out the more strongly in connexion with this resemblance and the general size.

In *Phascolomys vombatus* the form of the palate resembles that in *Phascolomys platyrhinus*. It is rather more concave in some individuals than in others in both species; and in the Platyrhine Wombat I have noticed a slight mesial ridge along the bony palate.

In *Phascolomys latifrons* the palate is not only more concave, but is wider anteriorly, less triangular; and at the hind part formed by the proper palatine bones, their median

suture rises as a longitudinal ridge dividing the bony palate there into two concavities or longitudinal channels, leading backward to the postpalatal apertures.

§ 11. *Mandibular characters of existing Wombats.*—In differentiating by cranial characters the species of Wombat called *Phascolomys latifrons*, I noted, in comparing it with *Phascolomys vombatus*, that "the curve of the lower border of the lower jaw is much deeper, the inner angle of the condyle is less produced, the coronoid process is higher and narrower, and the postsymphysial depression is almost obsolete in the Latifront Wombat"*. With the exception of the latter particular, which is variable in both species, subsequently acquired skulls have confirmed the constancy of the above characters. They likewise serve to differentiate the mandible of *Phasc. latifrons* from that of *Phascolomys platyrhinus*, except that the coronoid process rises higher in the platyrhine species (Plate XXII. fig. 2, *c*) than in the Tasmanian Wombat (ib. fig. 1, *c*); but the broader proportion of the process as compared with that in the Hairy-nosed Wombat (ib. fig. 3, *c*) is retained. The deeper curve described by the lower contour of the jaw from the neck of the condyle to the incisive alveoli, as shown in fig. 5, Plate xxxvii. of the undercited volume†, is a constant and well-marked character of *Phascolomys latifrons*; so, likewise, is the less produced inner angle of the condyle, shown in fig. 7, *c d*, of the same Plate. In both the Tasmanian and Platyrhine Wombats this angle is more produced and deflected.

The diastemal part (Plates XIX., XX. & XXI. *l*, *s'*) of the long symphysis (ib. *s*, *s'*) is subject to some variety in existing Wombats. In two mandibles of *Phascolomys platyrhinus*, in which the length of the series of molar alveoli is 2 inches 3 lines, that of the interval between the first alveolus and the foremost angle of the symphysis is, in one skull, 1 inch 7½ lines (Plate XXI. fig. 2), in the other 1 inch 6½ lines; the breadth of the diastema, midway, is the same in both, viz. 10 lines.

In a mandible of *Phascolomys latifrons* with the molar series of alveoli 2 inches in extent (Plate XX. fig. 1), the diastema (*l*, *s'*), taken as above to the foremost point at the interspace of the incisors, is 1 inch 6 lines; in a second mandible with the molar alveoli 1 inch 10½ lines in extent, that of the diastema is also 1 inch 6 lines: the breadth of the diastema, midway, is in the first mandible 8 lines, in the second 7 lines.

In the two mandibles of the Platyrhine Wombat compared, the diastema is slightly convex both lengthwise and across; it is traversed by a pair of shallow longitudinal grooves, and is not sharply defined from the sides of the symphysis. In a third mandible of the same species (Plate XIX. fig. 2, *l*, *l*) the defining ridges are better marked, the transverse convexity is less so; and this part of the symphysis is rather longer and narrower than in the other two mandibles. In these respects the third mandible approaches nearer to *Phascolomys latifrons*; but it differs, as do the other mandibles of the same species as well as those of *Phasc. vombatus*, in the larger, especially broader, incisive alveoli, and in the oblique course of their upper margins from the mid line of the sym-

* "On the Osteology of the Marsupialia" (Part II.) (1845), in Transactions of the Zoological Society, vol. iii. p. 304, plate xxxvii. figs. 2 & 5.

† Trans. Zool. Soc. vol. iii.

physis outward and backward. The fore end of the symphysis of *Phasc. latifrons* is at once recognizable by the narrower outlets of the incisive alveoli, and the more transverse course of their upper border (Plate XX. fig. 1, *s'*). The lateral borders of the outlets are also more nearly vertical, and do not slope backward as they descend, like those of the incisive alveolar outlets in *Phascolomys platyrhinus* and *Phasc. vombatus**.

With the narrower alveoli associated with the more compressed form of the incisors of *Phasc. latifrons*, one may predicate of a generally narrower diastemal part of the symphysis, the upper surface of which, with a mesial canal towards the end and the two parallel longitudinal grooves obsolete or nearly so, is better defined from the sides of this part of the symphysis. In one jaw of *Phasc. latifrons* the defining ridges are sharp, and the intervening upper surface is concave transversely to near the incisive outlets, where the defining ridges subside. I may note that the anterior outlet (*v*) of the dental canal in three mandibles of *Phascolomys platyrhinus* is 1 inch 4 lines, or 1 inch 5 lines behind the foremost point of the symphysis (Plate XXII. fig. 2, *v*): in one mandible of *Phasc. latifrons* (ib. fig. 3) it is 1 inch behind the fore end of the symphysis, in another mandible it is 10 lines from the same part. The foramen is more anteriorly situated in the broad-fronted or hairy-nosed species: it opens nearer to the molar series in *Phasc. vombatus* (ib. fig. 1, *v*)†. I may further note that in the mandibles of two individuals examined since describing that of the type skull of *Phascolomys latifrons*, the intercommunicating foramen from the entry of the dental canal to the outer surface of the base of the coronoid is smaller in one, as in the type mandible, than in the Platyrhine and Tasmanian Wombats, while in the other it does not exist. It is interesting to find this variety, because, in the great *Diprotodon* and *Notothere*, with some affinities to *Phascolomys*, the absence of the perforation of the base of the coronoid process is the rule, as in the Marsupialia generally.

The first lower molar (d_3) in *Phasc. latifrons* (Plate XX. fig. 1) has a subquadrate transverse section; in *Phasc. platyrhinus* (Plate XIX. fig. 2) and *Phasc. vombatus* (ib. fig. 1, d_3) it has an elliptic or ellipsoid transverse section. The masseteric fossa (Plate XXII., *f*) of the ramus ascendens, or "ectocrotaphyte cavity," is less deep in *Phasc. latifrons* (ib. fig. 3), and shallows more gradually forward, than in the bare-nosed recent species (ib. figs. 1 & 2); the inflected angle (*a*), viewed from below as in Plate XXIII., has a broader base in proportion to its length, and is not produced so far or directly backward in *Phascolomys latifrons* (fig. 3) as in *Phasc. platyrhinus* (fig. 1).

§ 12. *Mandibular characters of extinct Wombats similar in size to the recent species.*—I now proceed to apply the above characters and comparisons of the mandibles of the known existing kinds of Wombat in the attempt to elucidate the fossil mandibular

* This latter character differentiating *Phascolomys vombatus* from *Phasc. latifrons* is shown in figs. 3 *c* & 7 *c* of plate xxxvii. *tom. cit.*

† This character is shown in the figures of the mandible of the Tasmanian and Broad-fronted Wombats in plate xxxvii. of my second memoir (*tom. cit.*); but I could not then, as now, depend upon the constancy of such character.

evidences of similar-sized Wombats, of which I have received or worked out twelve specimens from the breccia-masses transmitted to the British Museum by the Trustees of the Australian Museum, Sydney, New South Wales, in conformity with the desire of the Colonial Legislature, and in connexion with their liberal vote in aid of further explorations of the bone-caves discovered by Sir THOMAS MITCHELL, C.B., Wellington Valley. Four other and more complete specimens are from the freshwater deposits of Queensland. The first of the cave specimens which I shall describe consists of the almost entire symphysis (Plate XX. fig. 2 & Plate XXIII. fig. 4), and it is the only specimen from the breccia which shows this instructive part of the lower jaw. With the bone are included the implanted bases of the incisors (*i*), the three anterior molars of the right side (d_3, d_4, m_1), and parts of the first and second molars of the left side. The upper surface of the diastemal part of the symphysis (*l*, *s*) is concave transversely, divided by sharp margins from the sides, and has a mesial longitudinal channel at the anterior third, without the pair of such channels. Lengthwise the upper contour of the diastema is slightly concave (Plate XXII. fig. 7, *l*, *s'*). From the fore part of the anterior molary alveolus to the broken end of the symphysis is 1 inch 6 lines; the breadth of the symphysis midway is 9 lines. So far the fossil shows a closer affinity to *Phascolomys latifrons* (Plate XX. fig. 1) than to the other two existing species, and more especially to the variety, fig. 3, Plate XXII.

This affinity is more decisively shown by the form of the incisors in transverse section (Plate XX. fig. 2, *i*, *i*) and of the anterior molars (ib. d_3). The enamel covers and defines the lower broad flattened side of the incisor, bending up a little way upon both outer and inner sides, which converge toward the upper, narrower surface, but unequally; the outer surface descending therefrom, at first more vertically, toward the base, while the inner surface slopes to the mid line of the symphysis as it descends.

Thus there is a greater interval between the upper than the lower sides of the two incisors; the vertical exceeds the transverse diameter of the transverse section of the tooth. In these characters the lower incisors of the fossil agree with those of *Phascolomys latifrons*.

In the Platyrhine and Tasmanian Wombats the transverse prevails over the vertical diameter of the exposed end of the incisors, and the enamel bends up from the lower along the outer surface nearly to the upper one, describing a uniform convexity, transversely.

The fossil adheres also to the latifront type in the shape of the first molar, d_3 (fig. 2, Plate XX.), and resembles the Hairy-nosed Wombat in the size of its molars, which is less than in *Phascolomys platyrhinus* (Plate XIX. fig. 2, d_3, d_4, m_1). But the following differences present themselves in the comparison of the present fossil with the corresponding part of the mandible of *Phascolomys latifrons*. In that species the upper transversely concave intermolar part or surface of the symphysis does not extend backward beyond the alveolus of the second molar; at the third molar the inner wall of the jaw soon changes its concavity for a convexity bending down to the back part of the symphysis. In *Phascolomys platyrhinus* the concave upper surface of the symphysis extends further back, and th character is exaggerated in the fossil; for the inner wall

of the socket of the third molar (Plate XX. fig. 2, m_1) arches inward as it descends, continuing the diastemal transverse concavity to that part of the molar series where the hinder fracture of the present fossil has occurred, exposing the long curved implanted part of the third molar (m_1, fig. 3).

Another difference is seen at the under part of the symphysis of the fossil (Plate XXIII. fig. 4) as compared with that in the latifront species (ib. fig. 3). In this the longitudinal contour is convex, concurrently with the greater general convexity of the curve of the lower border of the mandible (Plate XXII. fig. 3); in the fossil (ib. fig. 7) the lower surface of the symphysis runs straight, or very nearly so, from the hind fracture to the outlets of the incisive alveoli (s'), along a preserved symphysial extent of 2 inches 8 lines. It is interesting to see that here, again, the fossil resembles the Platyrhine species (Plate XXII. fig. 2), the older spelæan form combining to a certain extent characters kept apart in still existing species of Wombat. Nevertheless the more essential resemblances are to the *Phascolomys latifrons*. The pair of subsymphysial foramina (Plate XXIII. fig. 4, r) characteristic of the Wombats are wider apart (4 lines) than in the Platyrhine (ib. fig. 1, r) and Tasmanian (ib. fig. 2, r) species, and show rather the latifront character; they have the usual relative position to the fore and hind ends of the symphysis.

The specific distinction between the broad-fronted (Plate XXII. fig. 3) and other existing Wombats (ib. figs. 1 & 2) afforded by the ascending ramus of the mandible induced attention to all the cave fragments of that part of the lower jaw, and led to careful removal of the matrix from both the outer and inner depressions. This brought to light the modification of the lower part of the ectocrotaphyte depression (f) shown by the subject of fig. 6, Plate XXII. In the minor depth of the base or lower part of that depression the fossil mandibular fragment agrees with *Phascolomys latifrons* (ib. fig. 3, f), and more especially with the variety above noted with the absence of the transverse perforation (Plate XXII. fig. 3). The part of the base, or below the base, of the coronoid in the fossil where the canal opens externally in the normal mandibles of *Phasc. latifrons** is entire; it is also less depressed there than in the perforate variety. From this and the normal mandible of the latifront species the fossil (Plate XXII. fig. 6) differs in the relative position of the anterior beginning of the "ectocrotaphyte ridge" (h) or that bounding below the ectocrotaphyte depression (f). In the three recent species (ib. figs. 1, 2, 3) this ridge (h) begins near the lower border of the ramus; in the fossil (ib. fig. 6, h) it begins midway between the lower and upper borders, and on a vertical parallel with the third or antepenultimate molar (m_1)—consequently more in advance than in the recent Wombats, in which both the ridge and the base of the coronoid (g) begin below the fore part of the penultimate molar (m_2). Both penultimate and last molars are in place and are worn in the fossil, so the differences above noted cannot relate to nonage. The beginning of the ectocrotaphyte ridge is 10½ lines below the outlet of the first division of the alveolus of m_2 in *Phasc. latifrons* (ib. fig. 3, h), and is 1 inch below the same part in *Phasc. platyrhinus* (ib. fig. 2, h); in the fossil it is 6 lines below the hind

* Trans. Zool. Soc. vol. iii. plate xxxvii. fig. 5.

division of the alveolus of m_1. The anterior origin of the coronoid appears to be proportionally advanced in the fossil. The outer surface of the ramus below the beginning of the ectocrotaphyte ridge slopes more gradually inward and lower down before passing into the broad under surface of the jaw in the fossil (Plate XXII. fig. 6). In the recent Wombats the same surface curves, with a stronger and shorter convexity, into the lower border, yet less abruptly in *Phasc. latifrons* (ib. fig. 3, *k*) than in *Phasc. platyrhinus* (ib. fig. 2, *k*).

The ectalveolar groove is longer, deeper, and narrower in the fossil (Plate XIX. fig. 3, *u*), owing to the more advanced origin of the coronoid (*y*) and its greater proximity to the last two alveoli (m_2, m_3); this differential character is still more marked as compared with the Platyrhine species (ib. fig. 2, *u*). From so much of the entocrotaphyte ridge, or anterior beginning of the inflected angle, as is preserved, the degree of inflection appears to have been less in this fossil (Plate XXIII. fig. 5, *a*) than in the recent species (ib. figs. 1, 2, 3, *a*). The surface broadening as it recedes, between the ecto- and entocrotaphyte ridges, is not only flattened but becomes rather concave in the fossil toward the inner border.

The two hindmost molars in place (Plate XIX. fig. 3, m_2, m_3) are narrower than those in *Phasc. latifrons* (Plate XX. fig. 1, m_2, m_3), as are the anterior molars in the fossil previously described (ib. fig. 2, d_3, d_4). To the species represented by the last-cited fossil, I am disposed, from the resemblance of the symphysis to that in the imperforate variety of *Phasc. latifrons*, to refer the present fossil. They might be parts of the same mandible, as well as of the same species; but more complete specimens must confirm or confute this supposition. It is certain that both fossils show the nearest resemblance to the mandibular imperforate variety of *Phascolomys latifrons* above named, yet with marked differences, in value equalling those interpreted and accepted as specific. The part of the dental canal which courses along the inner side of the molar alveoli and the bottoms of the last two alveoli are exposed by fracture of the thin film of bone originally covering them.

In reference to the characters of the two portions of fossil mandible above defined, as they plainly justify the inference that they belonged to a species of *Phascolomys* as distinct from the three accepted recent species as these differ from one another, each might be indicated by a specific name; and it may ultimately prove that they do belong to distinct species.

The same remark applies to both or either in relation to the maxillary fossil from the same cavern (Plate XVII. figs. 2 & 6) which I have referred to a *Phascolomys Krefftii*.

Considering, however, that the two portions of mandibles combine, like that maxillary one, characters of affinity to *Phascolomys latifrons* with differential ones forbidding a reference to that species, it may be, and may be probable even, that they all belong to the same extinct species. I prefer, therefore, to indicate them as parts of a *Phascolomys Krefftii*, and leave to those who may be so fortunate as to obtain evidence to the con-

trary, to impose their own specific denominations on the so demonstrated distinct of Wombat.

§ 13. *Mandibular fossils of* Phascolomys latifrons.—Of six other mandibular ments showing the fore part of the ectocrotaphyte depression, two mutilated right (Plate XXII. figs. 4 & 5), by the gradual beginning and degree of deepening of depression (f), agree with the perforate or normal mandible of *Phascolomys lati*. The outer orifice of the transverse canal or perforation (ib. p) holds the same po in these fossils: one of them (ib. fig. 4) includes the four anterior molars and the s of the fifth; the other (fig. 5) includes the four posterior molars. The fore-a extent of the series of five sockets, in each specimen, is 2 inches, the depth of the dible at the back part of the symphysis is (in fig. 5) $6\frac{1}{2}$ lines; in fig. 4 it is 1 in lines. The ectalveolar groove (Plate XIX. fig. 4, u) is narrow. The inner wall c ramus, forming that of the second (d_3) and third (d_4) sockets, descends more verticall in the first described fragment (Plate XX. fig. 2), or in the Tasmanian (Plate XIX. and Platyrhine (ib. fig. 2) Wombats. The hind end of the symphysis is on the v parallel of the interval between d_4 and m_1, or not further back than the middle (Plate XIX. fig. 4, s'). In both these characters the present fossils come nearer latifront species (Plate XX. fig. 1, s) than to the Platyrhine and Tasmanian Wo The first molar (d_3) repeats the formal characters of that tooth in the *Phasc. lati*

I conclude, therefore, that the mandibular fossils under description belonge "hairy-nosed" Wombat, and one nearer to the existing species than the preceding (Plate XX. fig. 2), in which the symphysis appears to have extended as far back does in *Phascolomys platyrhinus* (Plate XIX. fig. 2).

§ 14. *Mandibular fossils of* Phascolomys Mitchelli.—I now come to man fossils which, in the depth of the base of the ectocrotaphyte depression (Plate fig. 5, f), resemble the Tasmanian and Platyrhine Wombats. Four of these ha entire molar series in place. In one (Plate XIX. fig. 5) the extent of the seri inches 2 lines; the first molar, however (d_3), agrees in shape and size with that in *latifrons* (Plate XX. fig. 1, d_3).

The transverse concavity of the inner wall, continued from the first and second sockets and upon the symphysis half an inch in advance, more resembles that in t perforate variety of the Latifront Wombat than in any other mandible of recent s The symphysis (Plate XXI. fig. 6, s) does not extend so far back as in the Tas (ib. fig. 1, s) and Platyrhine (ib. fig. 2, s) Wombats. From the fore part of th molar socket to the back part of the upper division (ib. fig. 6, s^*) of the sym surface, in the fossil, measures 1 inch; and this part of the symphysis is on the v parallel of the hind lobe of the second molar. The lower division (s) terminates fig. 4, below the interval between d_4 & m_1.

The fore part of the root of the coronoid, in the fossil (ib. fig. 5, g), stands on the alveolar wall of the penultimate molar, as in *Phasc. latifrons*; not from that last molar, as is the rule in the Tasmanian (Plate XXII. fig. 1, g) and Platyrhine (

2, *g*) Wombats. The extent of the molar series and the sizes of the individual teeth accord, save in the narrower character of the lower molars, with the teeth of the upper jaw in the subject of figure 5, Plate XVII. If these fossils are maxillary and mandibular specimens of the same species of Wombat, the lower molars are relatively narrower transversely, compared to the upper ones, than in any of the existing species.

In the mandibular specimen under consideration we see combinations of characters confined severally to distinct species in existing Wombats. I am disposed therefore, and for reasons above assigned, to refer this mandibular fossil, with the maxillary one above cited, to *Phascolomys Mitchelli*.

A second similar specimen of left ramus, including part of the symphysis and of the ascending ramus, has a molar series 2 inches in extent, and, as in fig. 5, Plate XIX., the teeth have the general characters of those in *Phascolomys latifrons*; they are transversely narrower than in *Phascolomys vombatus* or *Phasc. platyrhinus*. The ectocrotaphyte depression is deeper than in the perforate mandible of that species; the perforation (*p*) here shows a similar position and size. The depth of this fossil jaw at the back part of the symphysis is 1 inch 5 lines. The symphysis terminates below the interval, between the second (d_4) and third (m_1) molars. The ectalveolar groove is wider than in the subject of fig. 3, Plate XIX., but is deeper than in the Platyrhine and Tasmanian Wombats. The symphysis is not bilobed behind, as in fig. 6, Plate XXI.; but this and the before-mentioned differences from that subject probably exemplify the range and seat of variety in the mandibular characters of one and the same species.

The characters noted in the subjects of figs. 4 & 5, Plate XXIII., of fig. 4, Plate XXI., and of figs. 2 & 3, Plate XX., are of specific value; but, as in the maxillary fossils (Plate XVII. figs. 1 & 2), I do not feel grounds for indicating, after comparison of the mandibular fossils from the Wellington-Valley breccia-caves, more than two species of a size not exceeding the known existing Wombats, and not referable thereto.

§ 15. *Mandibular characters of* Phascolomys Thomsoni, *Ow.*—From the freshwater deposits of Queensland I have received mandibular fossils of the genus *Phascolomys*, which, with decrease of size, show characters not in accordance with those of any of the cave fossils.

The subject of figs. 8 & 9, Plate XVIII., and fig. 7, Plate XXI., is a right mandibular ramus, with slight mutilation at both ends. In the lower contour of the jaw, the depth of the ectocrotaphyte depression (*f*), the breadth of the ectalveolar groove (*u*), the position and size of the intercommunicating foramen (*p*), the shape of the anterior molar (d_3), and the shape and proportions of the incisor (*i*), so far as these are indicated, the present fossil agrees with *Phascolomys platyrhinus*, and differs from *Phascolomys latifrons* and *Phasc. Mitchelli*. It agrees, however, with these, and differs from both the bare-nosed Wombats, in the relative position of the back part of the symphysis (Plate XXI. fig. 7, *s*), which does not extend beyond the vertical line dropped from the front lobe of m_1.

The grinding-surface of d_3 (Plate XVIII. fig. 9) is an ellipse with the long axis nearly parallel with that of the mandible. The outer side of the incisor is transversely convex,

and curves uninterruptedly to the underside, as in *Phasc. platyrhinus* and *Phasc. vombatus*. In size this fossil does not exceed the Tasmanian species. The antero-posterior extent of the working-surfaces of the five molars is the same, viz. 1 inch 11 lines; but the teeth are rather narrower transversely, and the last molar, especially its hinder lobe, shows a greater decrease, as in the Hairy-nosed Wombat.

I indicate this modification of *Phascolomys*, from which the present fossil has been derived, by the name of the late estimable Professor of Geology in the Sydney University, New South Wales, ALEX. M. THOMSON, D.Sc. The specimen is from a lacustrine deposit at Gowrie, Darling Downs, Queensland, and was presented to the British Museum by Sir WILLIAM M^CARTHUR, Bart.

§ 16. *Mandibular fossil of* Phascolomys platyrhinus, *Ow.*—The subject of figs. 3 & 4, Plate XX., well exemplifies the differences by which *Phascolomys platyrhinus* differs from *Phascolomys Thomsoni*. The symphysis has the same backward extent and relative position to the molar series as in the recent specimen (Plate XIX. fig. 2); the character of the upper surface of the diastemal tract (l) is repeated; the formal characters of d_3 and of i in the fossil are precisely those in the recent continental bare-nosed Wombat: in size the fossil equals the largest living specimen of that species. The antero-posterior extent of the molar series is 2 inches 2½ lines. The shape and proportions of the molars characteristic of *Phascolomys platyrhinus* are closely preserved in the fossil. It was obtained from the bed of a tributary of the Condamine River, Queensland, by EDWARD S. HILL, Esq., and shows that the characters of the actual Platyrhine species were established at a period coeval with the existence of *Diprotodon* and *Thylacoleo*.

§ 17. *Mandibular and lower molary characters of* Phascolomys parvus, *Ow.*—With present evidence of the constancy of size of the molar series of teeth in existing and extinct species of Wombat, such series fully in place and well worn, having a longitudinal extent of 1 inch 5 lines, cannot be referred to a species with a longitudinal extent of molars never less than 1 inch 9 lines, and usually more: as, *e. g.*, in the Tasmanian Wombat, which is the smallest of the known existing species. The series of molars in Plate XIX. fig. 6, contrasted with those in fig. 1, is implanted in a mandible of similar small size (Plate XX. figs. 6 & 7). In the lower contour, the depth of the ectocrotaphyte fossa (f), the breadth of the ectalveolar groove, the shape and size of the incisor, and the shape of the grinding-surface of the anterior molar (d_3) this fossil agrees with *Phascolomys platyrhinus*. But the symphysis (Plate XX. fig. 7, s) does not extend so far back; it ends there below the interspace between the second (d_4) and third (m_1) molars. The hind contour of the symphysis is subbilobed (ib. s, s^*); it is long, but less deep relatively than in *Phascolomys Mitchelli* (Plate XXI. fig. 6).

The grinding-surface of the anterior molar (Plate XIX. fig. 6, d_3) is subelliptic, with the long axis nearly parallel with that of the jaw, 2 lines and 1 line in the two diameters, showing the usual disposition of the incomplete coat of enamel. The succeeding molars have the normal bilobed or biprismatic shape; their grinding-surfaces do not exceed severally 3½ lines, the fore lobe of the first (d_4) and the hind lobe of the last (m_3) being

the smallest. The hinder half of the diastemal tract, above, is bounded by a ridge (l) on each side, and is there transversely concave. The outlet of the dental canal (Plate XX. fig. 6, v) is more advanced in position than in *Phascolomys vombatus* (Plate XXII. fig. 1, v). The outer enamelled surface of the incisor is transversely or vertically convex, curving uninterruptedly to the lower border of the tooth, as in the bare-nosed Wombats, but with less relative breadth of the tooth than in those existing species. Sufficient of the angle of the jaw is preserved to show the partial division of the large cavity formed by its inward extension into the inner (d) and outer (e) angular depressions (Plate XXIII. fig. 7). The base of the coronoid process (Plate XX. figs. 6 & 7, c) is 6 lines in fore-and-aft extent; in *Phascolomys vombatus* it is 11 lines.

The well-marked characters of this small extinct species are satisfactorily repeated in a second mandibular specimen, also of the left ramus, but more mutilated behind. It retains, however, the anterior end entire; and the incisor shows its worn surface (Plate XIX. figs. 6 & 7, i). The vertical diameter of the incisor equals the long diameter of the working-surface of the second molar tooth, d_4.

A third illustration of this diminutive species is likewise afforded by a portion of the left mandibular ramus; it is a small portion, but includes the last two molars and the hind half of the antepenultimate molar. The base of the common plate of the coronoid and condyloid processes is in part preserved, with a broken beginning of the ectocrotaphyte ridge: these, with the postalveolar ridge and ectalveolar groove, repeat the characters of the more complete ramus (Plate XX. figs. 6 & 7). The size of both bone and teeth is the same in all. The present fossil, by the well-worn crowns of the molars, appears to be from an old individual. The formal characters are incompatible with a reference of those of size to immaturity.

All the specimens of *Phascolomys parvus* were in the Boydian Collection of fossils from the Lacustrine deposits of King's Creek, Darling Downs, Queensland, purchased by the British Museum, and are in the same mineralized condition as the remains of *Diprotodon* in the same collection.

I reserve for another communication the evidences of extinct Wombats exceeding in size the existing species.

Explanation of the Plates.

PLATE XVII.

Fig. 1. Upper view of anterior portion of skull of *Phascolomys Mitchelli*.
Fig. 2. Upper view of anterior portion of skull of *Phascolomys Krefftii*.
Fig. 3. Right side view of anterior portion of skull of *Phascolomys Mitchelli*.
Fig. 4. Left side view of the same skull.
Fig. 5 Under view of the same skull.
Fig. 6. Front view of the portion of skull of *Phascolomys Krefftii*.
Fig. 7. Portion of left maxillary, *Phascolomys Mitchelli*.
Fig. 8. Palatal surface and upper molars of *Phascolomys Mitchelli*.

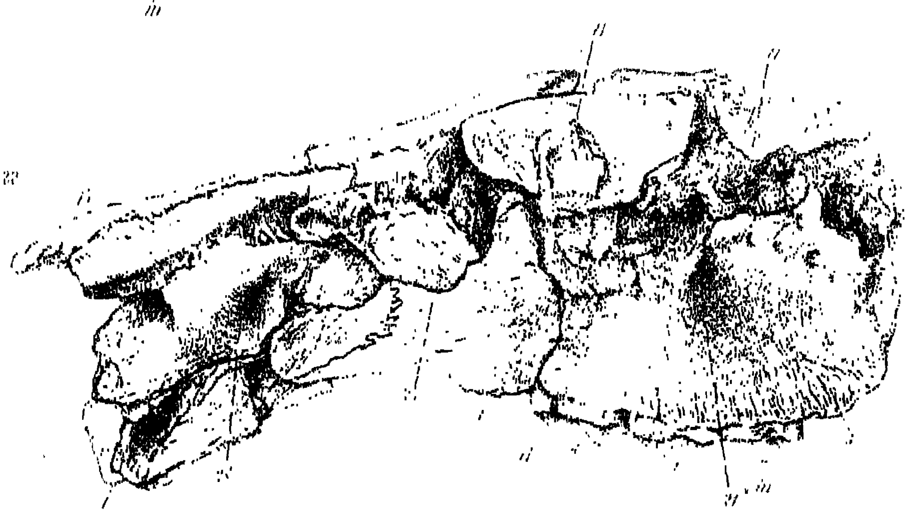


Fig. 2.

Fig. 8

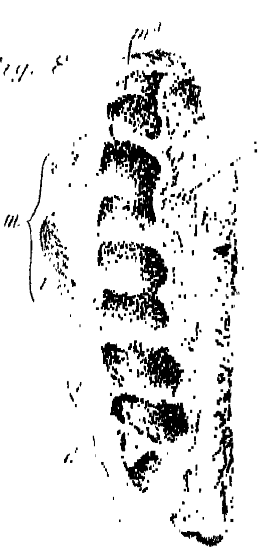


Fig. 5

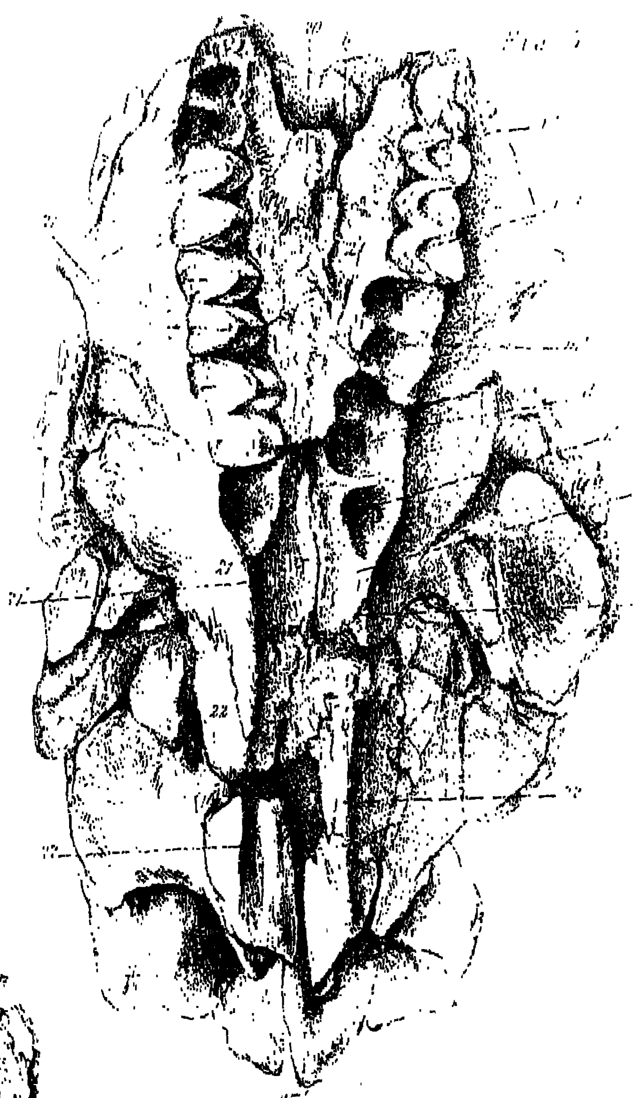


Fig. 7.

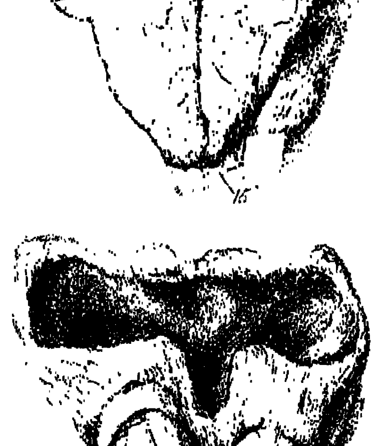


Fig. 6.

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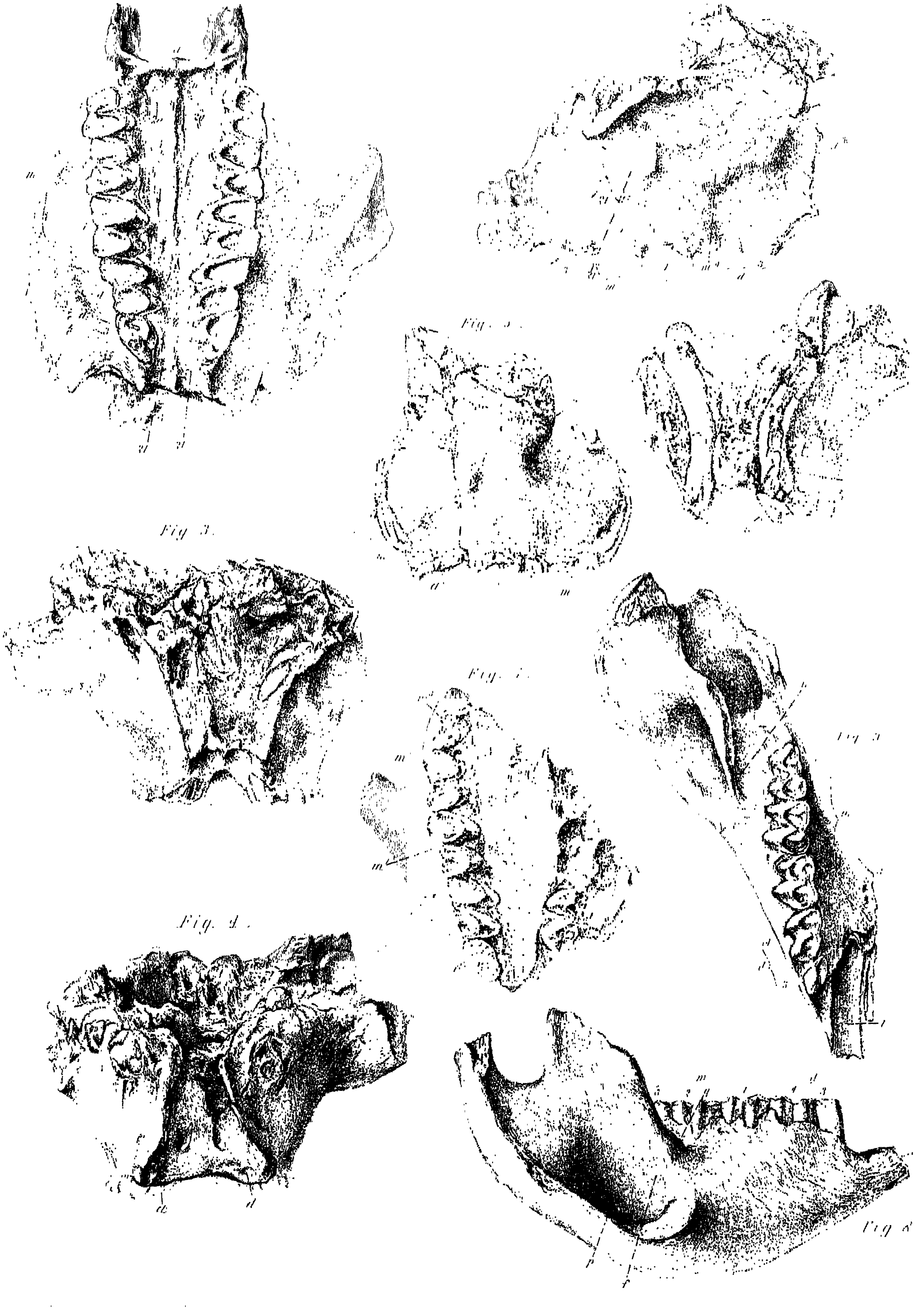

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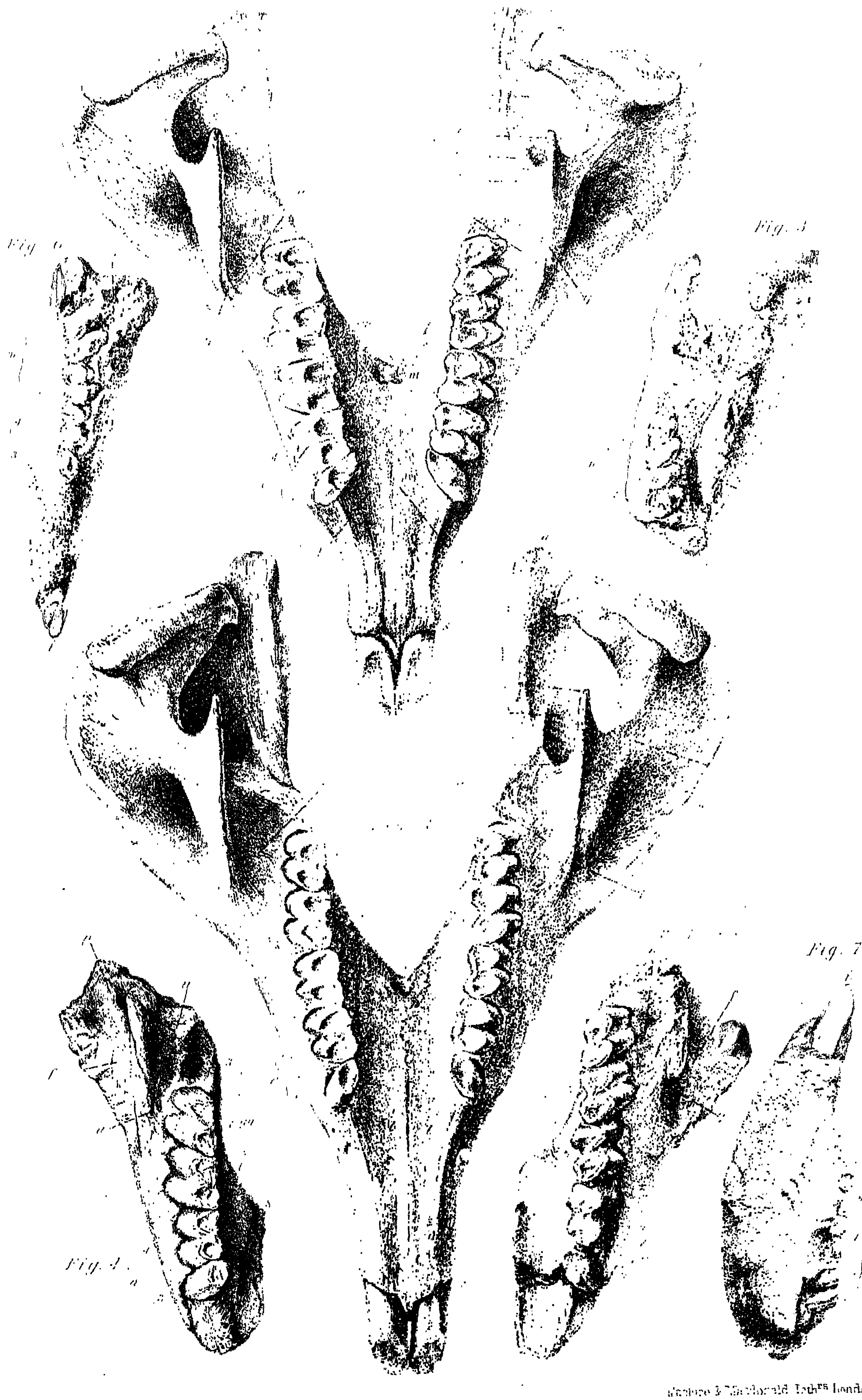

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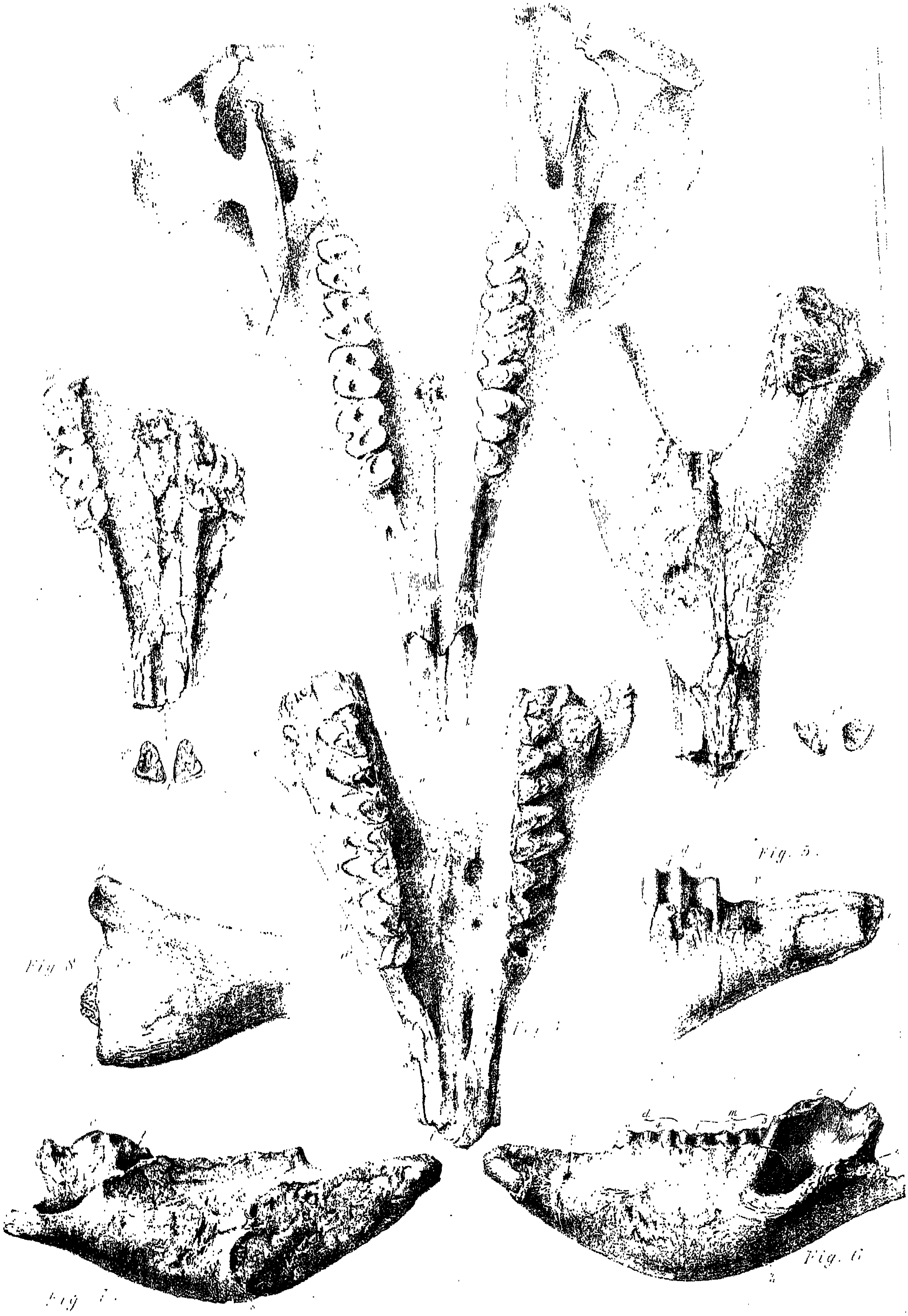
Fig. 5.
Fig 8
Fig. 6
Fig. 7.

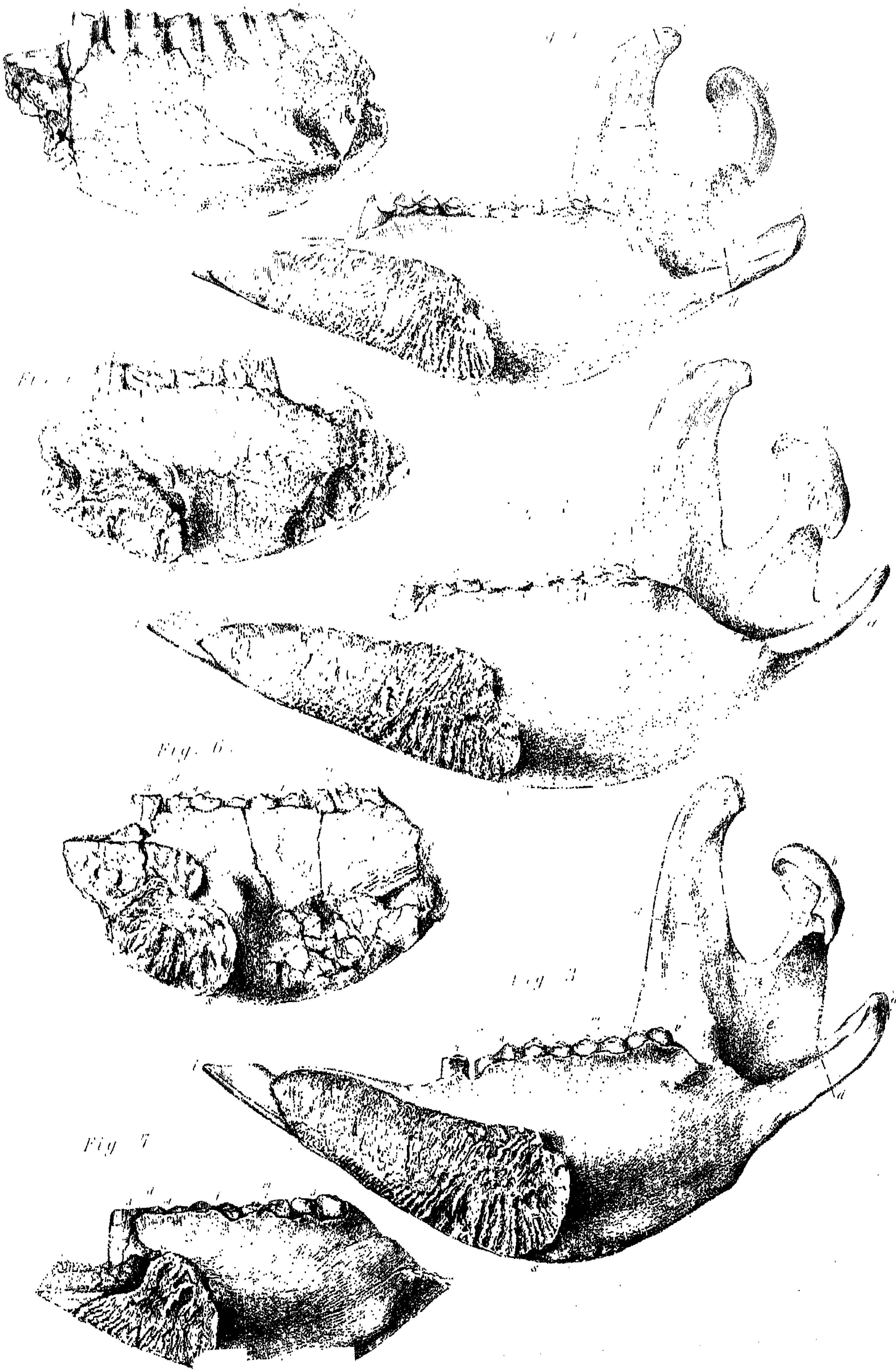
Fig. 6.
Fig. 7

PLATE XVIII.

Fig. 1. Palatal surface and upper molars, *Phascolomys Mitchelli*.
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PLATE XX.

Fig. 1. Upper view of mandible and mandibular teeth, *Phascolomys latifrons*.
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PLATE XXI.

Fig. 1. Inner side view of the right mandibular ramus, *Phascolomys vombatus*.
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Fig. 3. Inner side view of the right mandibular ramus, *Phascolomys latifrons*.
Fig. 4. Inner side view of a portion of the right mandibular ramus, *Phascolomys latifrons*.

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PLATE XXII.

Fig. 1. Outer side view of the right mandibular ramus, *Phascolomys vombatus.*
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Fig. 3. Outer side view of the right mandibular ramus, *Phascolomys latifrons.*
Fig. 4. Outer side view of part of the right mandibular ramus, *Phascolomys latifrons.*
Fig. 5. Outer side view of part of the right mandibular ramus, *Phascolomys latifrons.*
Fig. 6. Outer side view of the hind part of the right mandibular ramus, *Phascolomys Krefftii.*
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PLATE XXIII.

Fig. 1. Under view of mandible, *Phascolomys platyrhinus.*
Fig. 2. Under view of the left ramus and symphysis of mandible, *Phascolomys vombatus.*
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LIST OF WOODCUTS.

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All the figures are of the natural size.

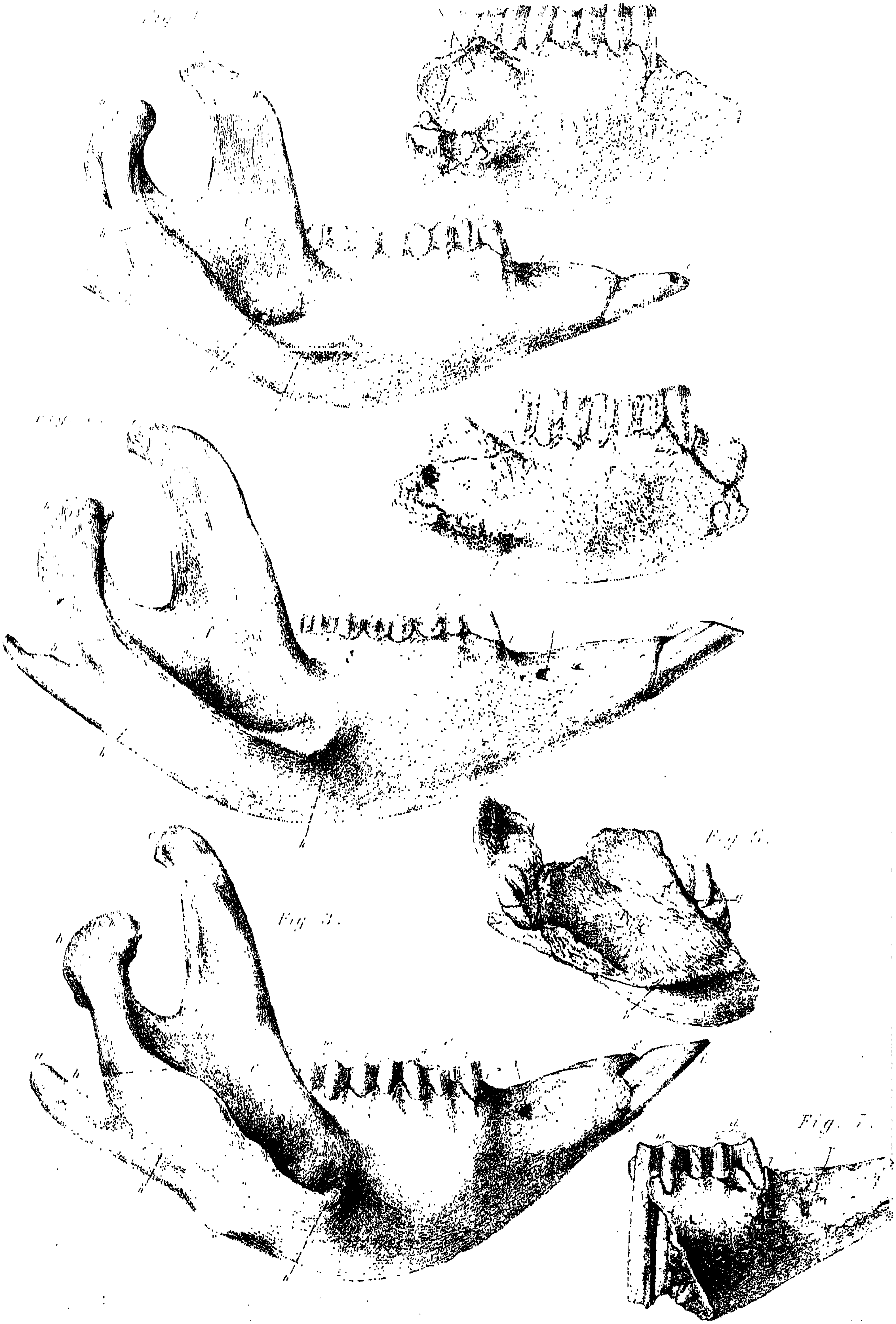

Fig. 3.

Fig. 6.

Fig. 7.

Fig. 7.
Fig. 6
Fig. 5
Fig. 4.

X. *On the Organization of the Fossil Plants of the Coal-measures.*—Part II. Lycopodiaceæ: *Lepidodendra and Sigillariæ. By* W. C. Williamson, *F.R.S., Professor of Natural History in Owens College, Manchester.*

Received June 13,—Read June 15, 1871.

In 1849, when M. Brongniart published his 'Tableau des genres des Végétaux Fossiles,' he admitted into his series of *Acrogenous Cryptogams* a family of Lepidodendra, in which he included *Lepidodendron*, *Ulodendron*, *Megaphyton*, *Halonia*, *Lepidophloios*, and *Knorria*. At the same time he recognized as *Gymnospermous Dicotyledons*, a family of Sigillariæ, including *Sigillaria*, *Stigmaria*, *Syringodendron*, and *Diploxylon*. He distinguished these two groups by supposed differences in the structure of the ligneous cylinder surrounding the pith. Speaking of this structure in the Lepidodendroid plants, he says, "Non-seulement il est continu et non divisé en faisceaux par des rayons médullaires, caractère que j'ai indiqué dans plusieurs familles très-diverses des dicotylédonés, mais les éléments qui le composent ne forment pas de rangées rayonnantes. Cette absence de direction radiée dans la disposition relative du tissu ligneux me paraît un caractère très-essentiel, car elle indique la formation simultanée de ce tissu, et non sa formation successive du dedans au dehors, caractère de la zone ligneuse des dicotylédonés"*. Describing his family of Sigillariæ, he says, "Le caractère essentiel de ces plantes, c'est de présenter, dans l'intérieur de leur tige, un cylindre ligneux entièrement composé de vaisseaux rayés ou réticulés disposés en séries rayonnantes, séparés en général par des rayons médullaires, ou par les faisceaux vasculaires qui, de l'étui médullaire se portent vers les feuilles"†. He further adds, "Les principaux genres de cette famille, ceux qui appartiennent sans aucun doute à de vraies tiges, présentent, en dedans du cylindre intérieur, sorte d'étui médullaire, continu et sans rayons médullaires dans le *Diploxylon*, divisé en faisceaux correspondant aux faisceaux principaux du cylindre ligneux dans le *Sigillaria*"‡.

I have long been engaged upon the study of the plants referred to in the above extracts. I have not only had the opportunity of examining numerous specimens in the cabinets of friends, but in nearly every instance I have literally dissected each specimen described, in my own lathe, so as to avoid, as far as possible, all sources of error. The result is that I am now in a position to demonstrate the complete unity of the plants which M. Brongniart has separated so widely, and to show that the transition from one form to another is so gradual as to necessitate the inclusion of the entire series in the Lepidodendroid family.

* *Loc. cit.* p. 39.   † *Loc. cit.* p. 55.   ‡ *Loc. cit.* p. 55.

That the *Sigillariæ* were Lepidodendroid is a conclusion that has been already arrived at, first by Dr. HOOKER and afterwards by Mr. BINNEY and Mr. CARRUTHERS; but the facts upon which this conclusion was based by these writers appear to me insufficient to furnish a demonstration of this affinity, since no example of a true *Sigillaria* in which the internal structure is preserved appears to have been hitherto described. Mr. BINNEY has described some plants* which he believes to be true *Sagillariæ*; but I agree with Mr. CARRUTHERS, who has pointed out that one of these† is a true *Lepidodendron*. Another‡ is a very curious and distinct plant of which I have sections, but which I have, as yet, failed to interpret; whilst the remaining plates refer to a plant which I shall notice further in this memoir, and which *may* be a *Sigillaria*; but I fear that we have not as yet sufficient evidence to render justifiable the conclusion that it is so. Mr. CARRUTHERS informs me that since his several memoirs referring to this subject were published, he has obtained such a *Sigillaria*, which he is about to describe; but not having seen the specimen I am unable to form any opinion respecting it.

My object in this memoir is to describe and illustrate the structure and affinities of several genera respecting which there is no longer any ground for doubt, and also to demonstrate the successive steps by which we ascend from the lowest type of *Lepidodendron* to stems which, as BRONGNIART has truly concluded, are furnished with an exogenous woody cylinder, richly supplied with medullary rays. For this purpose I shall take as my point of departure the *Lepidodendron* figured by Mr. BINNEY, already referred to, but which, in his specimen, lacked the outermost epidermal layer. This plant has also been described by Mr. CARRUTHERS§, who regards it as identical with the *Lepidodendron selaginoides* of STERNBERG. I owe some apology to the latter gentleman for redescribing a plant which, so far as he went, he has described so accurately; but to do so is indispensable to the object which I have in view, and which includes points not referred to in his memoir, as well as some others on which I am constrained to arrive at a different conclusion from his. He carefully abstains in his memoir from employing the terms medulla or pith, wood or ligneous cylinder, and bark; whereas I am satisfied that these three portions, characteristic of an exogenous growth, are to be discovered in the entire series of these plants. This threefold division is least conspicuous in the type just referred to; but a gradation of forms leads us from that type up to others in which the tripartite distinction is too remarkable to be overlooked. I have no doubt in my own mind respecting the existence of these divisions throughout the entire series; consequently in this memoir I shall speak of the medullary, ligneous, cortical, and epidermal layers, and I shall also always employ the same letters to indicate what I believe to be homologous structures in the various plants described.

* "A Description of some Fossil Plants, showing structure, found in the Lower Coal-seams of Lancashire and Yorkshire," Phil. Trans. 1865, p. 579.

† *Loc. cit.* pl. 35. figs. 5, 6.

‡ *Loc. cit.* pl. 34. figs. 1, 2, 3.

§ "On the Structure of the stems of the arborescent Lycopodiaceæ of the Coal-measures," by W. CARRUTHERS, Esq., F.L.S., F.G.S., Botanical Department, British Museum (Monthly Microscopical Journal, London, October

Plate XXIV. fig. 1 represents a transverse section of *Lepidodendron selaginoides*, from the cabinet of Mr. BUTTERWORTH, magnified six diameters. The medullary axis (*a*) consists of a very peculiar admixture of barred cells and vessels also barred. I abstain, as I have already done in my previous memoir on Calamites, from designating these vessels *scalariform*, because I have not yet found them to be thickened at their angles with continuous deposits of lignine, as is the case with the true scalariform vessels of ferns. Fig. 2 represents a longitudinal section of the same specimen, magnified four diameters. Fig. 3 is a small portion from the centre of the medullary axis of fig. 1, more highly magnified, and fig. 4 is a corresponding enlargement of the same structure, though less highly magnified, of fig. 2. The cells of this structure in the specimen figured exhibit a tendency to diverge into two forms. We have one thick-walled series, arranged in vertical rows (fig. 4, *b*), the transverse septa of which are sometimes rectangular in relation to their sides, but much more frequently oblique, the obliquity tending sometimes in one direction, and sometimes in another even in the same pile. The sides and ends of these cells are alike richly barred. Sometimes the bars are regularly parallel with each other, and arranged transversely as in the vessels; but very frequently they describe a series of curves as if one, two, or even three of the angles of the cells had been centres from which corresponding series of concentric segments of circles had been drawn. In the transverse section these cells also appear barred on their transverse partitions (fig. 3, *b*), the bars being usually arranged in two opposed systems of curves. These barred cells vary in diameter from ·005 to ·0015*. The cells of the other class are much smaller, have very thin walls, and appear to be small masses of ordinary parenchyma intermingled with the other medullary tissues; it is possible, but not probable, that this difference is due to mineralization, a point to which I shall return. The vessels (figs. 3 & 4, *c*) are often almost undistinguishable from sections of the barred cells; indeed we appear to have here strong evidence of their primarily cellular character. In the specimen figured, those of the centre of the medulla are somewhat widely separated by the two kinds of cellular tissue as shown in fig. 4; but this separation only extends over a small area. In the peripheral portions of the medullary axis they are closely conjoined, the cellular element becoming less abundant, especially the delicate parenchymatous tissue which is so much more copious in the centre of the structure. These vessels range from ·0014 to ·002 in diameter.

Immediately investing the medullary axis is a thin cylinder (figs. 1 & 2, *e*) of small barred vessels arranged in parallel series radiating from the medulla outwards. These represent the ligneous zone. The innermost ones are exceedingly minute, and though they increase in size as we proceed outwards, they rarely exceed ·016 in diameter, the great majority of them being very much smaller. It is from the innermost surface of this cylinder that the vascular bundles are given off to the leaves, a point of importance in determining the homologous relationships of the various portions of the Lepidodendroid plants. The radiating arrangement of these vessels suggests, as the quotation already

* All these dimensions refer to decimal divisions of an inch.

made from the writings of M. BRONGNIART points out, an exogenous mode of growth, a conclusion fully borne out by facts yet to be mentioned; small cells arranged in single or double vertical rows pass outwards, like medullary rays, between these vessels. The tissue immediately surrounding the ligneous zone has almost always disappeared from the specimens of this plant, its place being represented by an almost vacant space; but there are indications, as Mr. CARRUTHERS has correctly pointed out, that it has been a delicate form of parenchyma. In the present example almost every trace has disappeared save a narrow ring (*g*) of disorganized carbonaceous matter at some little distance from the ligneous zone. The space within this tissue represents the innermost portion of what I regard as the cortical layer. Scattered through this vacant space, as well as the more external one, we find in the transverse sections small bundles of minute scalariform vessels (fig. 1, *m*) fringed round with delicate parenchyma, and exhibiting a circular or oval section. Their diameter ranges from ·003 in the round sections near the ligneous zone to a longer axis of ·007 in the more peripheral portions.

We now come to the middle bark (*h*), a dense, well-preserved layer of thick-walled parenchyma, gradually passing into prosenchyma at its outer margin. The rounded cells of the former have a mean diameter of about ·003, gradually becoming more oblong, with a longer axis of about ·007 and a shorter one of ·002. The foliar vascular bundles make their way through this layer, the delicate parenchyma with which each bundle of vessels is surrounded gradually merging with its coarser cells. The delicacy of this parenchyma investing the bundles frequently leads to its entire disappearance, leaving blank spaces (*m'*) channelled through the bark, in the middle of which the barred vessels of the foliar bundles are sometimes conspicuous from their isolation. As the parenchyma of this middle bark becomes converted into prosenchyma at its outer portion, its cells become elongated vertically, and at last pass rapidly into the almost vascular form of prosenchyma (*k*), constituting the bast-layer of the outer bark. In the transverse section these tubes are seen to be arranged in radiating series proceeding from within outwards. In the vertical section the more external ones become as elongated as in the pleurenchyma of many exogenous barks, the fibres being arranged longitudinally in curving lines having a very regular parallelism. They have a mean diameter of about ·00083. Towards the outermost portion of this tubular prosenchyma we find, in these fossils, a tendency to split vertically, and to the consequent detachment of the epidermal layer (*l*). The innermost portion of this detached layer consists of tubes precisely similar in every respect to those of the outer bark, but which again change rapidly, as we proceed outwards, first into the prosenchymatous form seen in the middle bark, and then into a thick-walled parenchyma which constitutes both the superficial portion of the epidermis and the entire substance of the petioles or bases of the leaves (*l*). I have here referred the tubular bast-layer partly to the outer bark and partly to the epiderm, because, when the latter becomes detached, the line of separation usually passes through the middle of the layer; but it may perhaps be more correct to regard the whole of these bast-tissues as one subepidermal layer. Fig. 5 exhibits a tangential

section of the outer bark passing through the prosenchymatous layer and immediately underlying the epidermal one; but owing to the cylindrical form of the specimen, on the left hand of the sketch the section has passed outwards through the latter layer (fig. 5, *l*) and the attached bases of the leaves. The prosenchymatous character of this bark-tissue is well shown in this section. Openings, indicating the points through which the foliar bundles of vessels have passed, are seen to be partly occupied by delicate cells. The section of each opening is oblong in a vertical direction. Fig. 6 is a tangential section made parallel to the last, but through the outermost epidermal layer (*l*). The bases of the leaves are here indicated by large lozenge-shaped spaces (fig. 6, *l*), arranged, like the corresponding openings in fig. 5, in quincuncial order. These two sections illustrate, with great clearness, the tissue to which two common appearances seen amongst fossil *Lepidodendra* belong. Fig. 5 represents the *Knorria*-like forms which are commonly, but erroneously, spoken of as *decorticated*; whereas they belong chiefly to the outermost surface of the middle cortical layer, the bast-layer and epidermis alone having disappeared: such a surface, in the plant under consideration, is represented in fig. 7. In some larger stems of this, or an almost identical species, belonging to J. B. Dawkins, Esq., the lenticular projections are rather shorter and broader than those in this figure. Fig. 5 corresponds to the ordinary *Lepidodendra*.

The sections of the persistent bases of the leaves (*l*) vary considerably in form, as is shown by figs. 1, 2, 5, & 6. So far as the transverse section is concerned, fig. 1, l'', appears to indicate the characteristic form, since its resemblance to a depressed acuminate leaf reappears with more or less of distinctness in most of the other sections made in the same plane. These petioles consist of coarse thick-walled parenchyma, the cells in some portions not unfrequently appearing elongated in the direction of growth. The cells of the exterior surfaces are small and dense.

I have mentioned that in the medullary axis of the specimen described there is a very distinct appearance of two kinds of cells, but I am far from certain respecting the true signification of this difference. In other sections of the same species of *Lepidodendron* I find similar appearances, but with more semblance of a transition from the barred and thick-walled to the thin-walled cells; whilst in one specimen, the centre of which, however, is considerably disorganized, every cell, large and small, appears as if it had been equally barred. I have long since learnt that amongst these coal-plants the absence of a barred or reticulated structure from a cell or vessel is no proof that such secondary elements never existed. We frequently find that, during mineralization, the carbonaceous matter, representing the original deposits of lignine, has been diffused in a uniform, granular layer over the walls of the tissues. Hence it is barely possible that the variations in the medullary cells of the plant described are due to such mineralization.

It appears that, in this plant, we start at the centre with a highly vascular axis intermingled with cellular tissue, and that the vessels, though diffused over the entire medulla, exhibit a slight tendency towards a peripheral polarity, being less intermingled with cells at the exterior of the medulla than at its centre. Around this we have a thin layer

of vessels which exhibit an exogenous arrangement, and have, passing outwards between them, thin vertical layers of cells which I believe to be early forms of medullary rays. Mr. CARRUTHERS rejects this interpretation; but I think I shall be able to show, in the course of my descriptions, that they are what I have affirmed them to be. Mr. CARRUTHERS objects to the idea of their being medullary rays, because "the axis of the stem is not occupied with a cellular medullary tissue, but with scalariform vessels" *; and that consequently "it cannot be interpreted as similar to that of the medullary system of Dicotyledons." Experienced as my friend and co-worker in the field of phytology is, I must venture to differ from him here. He recognizes, in his description, the existence of the scalariform cells which I have also described, though in phraseology different from my own. "Some of those (vessels) in the centre of the axis are divided into chambers by horizontal septa, or rather they appear to be made up of a series of short, obtuse cells, whose transverse as well as longitudinal sides are marked with scalariform bars. Such interrupted vessels are scattered irregularly through the others. I can detect no trace of any other structure in the axis than scalariform vessels" †. I submit that such tissues as are here so correctly described cannot, in any accepted sense of the term, be called *vessels*; they are *cells*, which it is true might by fusion become vessels. In their earliest state they were not barred or scalariform, but simply forms of parenchyma.

In seeking an explanation of the philosophy of these medullary rays, we must not limit our attention to their matured state, but go back to the time when all the tissues associated with them existed as a cluster of undifferentiated parenchymatous cells. One of the first changes to be detected would be the development of a few vessels, and amongst others would ultimately appear those destined to constitute the incipient exogenous ring. The moment these made their appearance, they converted the few cells which separated them into incipient medullary rays. Thus much of a change might occur before the cells deposited in their interiors their bands of lignine which give them their barred or scalariform structure. It would not be necessary that, as growth advanced, all the cells should follow the same course of development. Such we know is never the case in the higher plants; were it so, differentiation of tissues would be impossible. Further, I think Mr. CARRUTHERS must differ from me as to the essential characters and functions of medullary rays. Though in their earliest state their purpose is doubtless to connect the medulla with the more external tissues, such is not their permanent function. As exogenous stems grow, the pith gradually contracts, and what cells remain do so in a final condition that rather represents effete structures than active cells filled with vigorous protoplasm. Yet though the medulla becomes thus altered, and its primary mission a thing of the past, the medullary rays continue to grow and actively fulfil their essential functions, which is to maintain free lateral communication between the inner and outer layers of the wood, and between both these and the bark. If this reasoning is sound, and I believe it to be so, the fact that a matured Lepidodendroid stem has its medullary axis occupied in some cases with barred cells, and in others

* Monthly Microscopical Journal, October 1869, p. 180. † *Loc. cit.*

even with barred vessels, in no way militates against the conclusion that the vertical piles of mural cells which separate the laminæ of the vessels constituting the woody zone, and which are constantly extending in a peripheral direction, are true medullary rays. Their earliest genesis, combined with their final functions, rather than the degree of differentiation which the several tissues have finally undergone, determine their nature.

I shall shortly demonstrate that, simple as these rays are in their early form, they become very definite when we ascend to some of the higher developments of the ligneous zone which we shall find amongst these Lepidodendroid plants.

If I am correct in these determinations, no question can arise as to the cortical nature of the thick, investing, and more external layers, with their prevalence of prosenchyma, so characteristic of Lycopodiaceous cortical structures. We also see that the retention on the epiderm of portions of the bases of the leaves hides what should otherwise represent the regularly arranged leaf-scars seen in the common Lepidodendroid stems. Whether, in the species under consideration, these leaf-petioles were persistent, or whether, as the stem advanced in age, they fell off, leaving a natural cicatrix of the forms represented in fig. 6, is doubtful; but my present belief is that the latter was the case, and that the fact explains why we only find such examples as I have figured of comparatively small size.

I have sections of one example of the above type from South Owram, near Halifax, and for which I am indebted to Mr. NEILD of Oldham, in which the cellular element of the medullary axis is reduced to its minimum. The axis consists mainly of barred vessels; nevertheless cells exist in sufficient numbers to demonstrate the identity of the two forms. The next modification of the Lepidodendroid type to which I would call attention is one that Mr. BINNEY has included, together with that which I have just described, in his memoir on *Sigillaria* already referred to, but which I agree with Mr. CARRUTHERS in regarding as a distinct plant. None of the specimens of it which I have had the opportunity of studying exhibit the outermost layer of the bark; consequently I know nothing of its external contour, but the portions which I possess are interesting and instructive. Plate XXV. fig. 8 represents a transverse section of the central axis (a, c), with the ligneous zone (d) and the inner portions of the bark (g, i), of a specimen in Mr. BUTTERWORTH'S cabinet, besides which I have made numerous dissections of some other specimens of the same type, with which Mr. BUTTERWORTH has kindly supplied me. The prominent features in the medullary axis of the specimen figured are the entire absence of vessels from its central portion, and its transverse division into two longitudinal halves, by a line extending on each side from its central cellular portion to its periphery. Mr. BINNEY has correctly represented this structure*; but he says respecting it, "The dark line across the axis, as well as the dark space in the centre, both seem to be the result of a disarrangement of the tubes during the process of mineralization, as similar appearances have not been observed in many other specimens examined by me, which in those parts are in a more perfect preservation"†. I

* *Loc. cit.* pl. 32. fig. 1 & 2.

† *Loc. cit.* p. 587.

feel constrained to differ from the above conclusion, to which, I think, Mr. BINNEY has been accidentally led by uniting two plants, which, though very closely allied, are nevertheless distinct, viz. the one which I have just described and that now under consideration. The dark central portion of the medulla is a compact mass of cells, as is well seen in Plate XXV. fig. 9, *a*. No vessels appear in their midst, and the dividing line, extending on each side to the woody zone, is a prolongation of the same cellular tract*. The cells average from ·01 to ·0025 in diameter, their length being variable. As in the preceding instance, they are generally arranged in vertical piles, but with great irregularity in the obliquity of their horizontal or transverse septa. This peculiar obliquity of many of these cell-partitions in the cells traversing the long axis of the stem appears to be a characteristic feature of most of the Lepidodendroid plants. All these cells in the plant before us have had barred walls. External to this cellular axis we have a dense ring of barred vessels (figs. 8 & 9, *c*). At the inner portion of the ring they are detached from one another, masses of the barred cells ramifying between them; but towards its exterior portion the vessels become a compact mass. They have a varying diameter of from ·01 to ·0025, but the most peripheral series in immediate contact with the ligneous zone are not more than ·0012. The entire series is arranged, in transverse sections, in parenchymatous fashion, being wholly devoid of any linear disposition, and small tubes being packed into the interstices amongst the larger ones.

One of the striking and characteristic features of this plant is its well-developed ligneous zone (figs. 8 & 9, *d*). This consists of barred vessels, arranged in very regular radiating lines. In the specimen figured, there are not more than seventeen or eighteen of these vessels in each radial series; but in another section, in my cabinet, of a stem which, though deprived of its epidermal layers, has been fully 2½ inches in diameter, the woody zone has a breadth of ·37, and each linear row contains about 80 vessels. As usual the innermost of each series are the smallest, and they increase in size as they proceed outwards. The medullary rays are very abundant (Plate XXV. figs. 9 & 10, *f*). In the tangential sections (fig. 10) they are easily recognized; but, owing to the delicacy of their texture, a superficial observation easily leads to their details being overlooked in the radial sections. They are nevertheless most distinct, sweeping across the vessels in straight and parallel lines from the medullary to the cortical surface of the ligneous zone; precisely as they would be seen to do in a corresponding section of any exogenous wood. The exogenous growth of this portion of the stem is sufficiently obvious. We have the radiating arrangement, and the regular increase occurring in the number of vessels in each linear row, as the stem enlarges its diameter. The new vessels have not been intercalated, but added to the exterior of each series,—a fact often rendered evident by the circumstance that, from their walls being less strengthened by ligneous deposits than in the case of the older vessels, they are much more liable to be disturbed and disarranged by lateral pressure.

* Other specimens have come under my notice, in which the medullary vessels encroached almost entirely upon the inner parts of the pith; nevertheless there remained the central spot, of which the transverse line dividing the medulla into two halves is the lateral extension.

The next distinctive feature in all the examples of this type which I have examined is seen in the inner and middle bark. Instead of a thick parenchyma, we have here very little of that tissue. I had for some time a difficulty in satisfying myself that any existed; but I think that the crushed and disturbed structures represented in figs. 8 & 9, *g*, have been parenchymatous. Almost immediately after leaving the woody zone, the tissues of the bark become conspicuously prosenchymatous, the cells, as seen in the transverse section (fig. 8, *i*), being arranged in radiating lines, and bearing the closest possible resemblance to a corresponding section of the *wood* of an ordinary coniferous plant. But on turning to the radial and tangential sections (fig. 9, *i*), we see that this tissue consists of simple prosenchyma, the walls exhibiting no traces of the pits or extensions of the protoplasm through the ligneous cell-layers to the primary cell-wall, seen in the true pleurenchyma of Conifers and of the hard endocarps of fruits. These cells have a length of ·022 and a diameter of ·0025. Their general aspect is represented in Plate XXV. fig. 11. The outer bark is not represented in the figure; but in the transverse section it merely presents a continuation, outwards, of the same linear series of cells as is shown in fig. 8, *i*, while in the radial sections we find that the prosenchymatous cells are now drawn out into very long tubes, such as are found immediately beneath the epidermal layer of *Lepidodendron selaginoides*. The entire thickness of the bark in my specimens, deprived of its epidermal layer, is about ·62. We have distinct evidence that bundles of vessels are given off from the woody zone of this plant to the leaves. Three such are represented in fig. 8, *m*; but these are very much less obvious than in the case of *Lepidodendron selaginoides*. We do not find here regularly disposed channels ploughed conspicuously through the bark; without careful observation the bundles would easily be overlooked.

The next type to be described, and which I believe to be identical with the *Lepidodendron Harcourtii*, leads us in the opposite direction from that just discussed. In its general aspect it approaches nearer to *L. selaginoides*; but it has its own distinctive features, which lead us further away than any of the other instances from the exogenous type of structure. Plate XXV. fig. 12 represents a transverse section of the natural size, in the cabinet of W. Boyd Dawkins, Esq. It was prepared from a fine specimen collected by J. Aitken, Esq., of Bacup. In Plate XXVI. fig. 13 a small portion of this section is more highly magnified. Plate XXV. fig. 14 is the central axis, with a small portion of the inner bark, yet further enlarged; and Plate XXVI. fig. 15 represents the outer surface of the outer bark on the removal of the epidermal layer, but taken from another specimen of the same type as that from which the sections were prepared, and for which I am indebted to Mr. Butterworth.

The medullary axis (*a*–*c*) is about ·25 in diameter, of which the central cellular portion (*a*) occupies about ·18. This consists of cells arranged in irregular vertical rows, and frequently with the oblique transverse septa so common amongst the Lepidodendra. I can detect no trace of barred structure in these cells; but, as their walls are thickened with a deposit of brown carbonaceous matter, I think it very possible that this deposit

may represent the disorganized cell-fibres of barred cells. The exterior of the medullary axis is occupied by the usual ring of barred vessels, but it is much narrower than in the previously described types, being not more than ·035 in breadth. Yet more remarkable is the almost complete absence, from the transverse section, of the woody zone. In figs. 12 & 13 it is scarcely visible, but it may be represented by the minute barred vessels of the vertical section (fig. 14, *d*). The inner bark (*g*) consists of parenchyma, the cells of which are very minute, being rarely more than ·0012 in diameter. More externally we have a very thick middle bark, consisting of a coarser parenchyma (*h*) with larger cells, and about half an inch in thickness. External to this are the radiating lines of a thin subepidermal layer of prosenchyma (*i*), about ·06 to ·12 in thickness, the transition from the coarse parenchyma of the middle bark to the elongated prosenchyma being very abrupt. The outermost layer of epiderm is wanting in all the specimens which I have seen of this type. I have not had the opportunity of examining the original specimen in Mr. Aitken's cabinet; but Mr. Butterworth's example of the same plant, from South Owram, exhibits the subepidermal surface of the outer bark, which is covered, not with oblong projections, as in the case of *Lepidodendron selaginoides*, but with hexagonal areola about a quarter of an inch in breadth, as represented in fig. 15. This distinction shows that, though in their internal organization the two plants approach very nearly to one another, they are nevertheless different. The aspect of the well-marked vascular bundles proceeding to the leaves (*m*, figs. 13, 14) is also different. They leave the thin vascular zone, and plunge into the parenchymatous bark with little or none of the perishable investment derived from the delicate cells of the inner bark seen in *Lepidodendron selaginoides*; hence they appear in all the sections as dark radii of well-defined vessels without any open space between them and the bark itself.

Before leaving these examples of the genus *Lepidodendron*, I would call attention to some sections which illustrate yet more clearly the nature of the apparently persistent petioles that adhere to the bark of some examples, and also throw light upon the scars that characterize the Lepidodendroid stem. Plate XXV. fig. 16 represents a section kindly lent to me by Mr. Dawkins, who also obliged me further by placing in my hands half of the specimen from which the section was obtained. It is a radial longitudinal section of the epidermal layer of a *Lepidodendron* with its attached petioles; 16 *k* is the layer of tubular prosenchyma constituting the subepidermal tissue in all these plants; *i* is a fragment of the outer bark, consisting of the ordinary forms of short prosenchymatous cells; whilst at *l* we have a series of petioles, which, in this section, appear to be turgid and succulent at their bases, but become more shrivelled and thin as they ascend outwards from the bark. The specimen supplied to me by Mr. Dawkins enabled me to make a series of sections of these petioles. Plate XXVI. fig. 17 represents a tangential one made through the bases of the petioles external to the subepidermal prosenchyma, 16 *k*. The petioles are here in close contiguity, and of more or less regular rhomboidal forms. The position of the vascular bundle going to each leaf is indicated faintly in a few of the petioles by a rather darker spot (*m*). Plate XXVI. fig. 18 is a section made

nearly parallel to the last, but a quarter of an inch nearer the free extremities of the leaves. Each petiole is now seen to be deeply indented by a sharply defined groove running along the centre of its upper surface, which appears to have become generally depressed, the lower surface having undergone little change of form; but the two margins of each petiole have become winged or prolonged laterally into broad membranous expansions (18, *l'*), explaining corresponding appearances seen in the longitudinal section (16, *l'*). These membranous expansions are mutually disposed with the utmost regularity, the one proceeding to the right, from each petiole, always overlying the margin of that approaching it from the opposite direction. The position of the vascular bundle of each petiole is now very distinctly marked by a small semilunar opening (*m*), from which the vessels have disappeared. A corresponding section of the specimen represented by fig. 20 displays this sharply defined semilunar orifice yet more strikingly.

The section Plate XXVI. fig. 19 is a transverse one, made in the line *x*, *x* of fig. 16, so as to intersect some of the petioles near their extremities, and yet at right angles to their longer axes, as is done at *l''*. They are here seen to have become yet thinner and more flattened at their central portions, though retaining the central groove on each upper surface. The same regularity in the superposition of the thin margins is found here as in fig. 18. Fig. 19, *k* represents the layer of tubular prosenchyma, and *l* the turgid bases of three more petioles. That the latter only exhibit the marginal membranous expansion on one side (19, *l'*) is due to the fact that the section has passed obliquely through the petioles, and only crossed in the plane of those expansions on one side. Plate XXVI. fig. 20 is a longitudinal section of a fragment of the same species of *Lepidodendron* as the last, supplied to me by Mr. WHITTAKER, of Oldham, and which I have figured because it displays very clearly the somewhat elongated form of parenchyma of which these petioles consist. At their free extremities the latter have become yet more membranous than is the case with those of the corresponding, but less highly magnified, figure 16. This difference indicates that the shrivelling process incident upon the decay of the leaves has been, as might be expected, a gradual one; and that by the time it reached the portions of the petioles represented in the tangential section fig. 17, a natural cicatrix would have been formed at which the decay would be arrested, and which, when the shrivelled portion had fallen away, would exhibit the ordinary lozenge-shaped scars seen in the common examples of *Lepidodendron*. The generic distinctions that have been drawn between types that retain and others that do not persistently retain their petioles, appear to me to be of more than doubtful value, since, in all probability, they represent temporary rather than permanent conditions. That some species have retained their petioles longer than others is sufficiently probable, but I believe this to be all that is implied by such differences.

Resuming the task of tracing the development of the exogenous type amongst these Lepidodendroid stems, we come to a series of specimens of which that represented in Plate XXVIII. fig. 21 & Plate XXVI. fig. 22 is a marked example. These plants correspond very closely with the *Anabathra* of WITHAM and with the *Diploxylon* of

CORDA, but they are unmistakably Lepidodendroid in structure. The different examples which I have seen exhibit variations in the development of the medullary rays in the ligneous zone; but I can trace no distinctive feature separating the extreme modifications; consequently the one which I have figured may be accepted as a fair and well-marked example of its class. The characteristic feature of all these specimens is that they have a medullary ring of barred vessels (*c*) *not* arranged in linear or radiating order, surrounded by a well-developed woody zone of smaller barred vessels which *are* arranged in linear series (*d*), the whole having been encompassed by a parenchymatous or prosenchymatous bark (*g*). The centre of the axis is vacant, but whether primarily fistular, or occupied by some other tissue, remains to be considered. In the example figured there are as many as 130 vessels in each radiating linear series seen in the transverse section of the woody zone. On making a tangential section of a portion of the same zone (Plate XXVII. fig. 23), we discover that medullary rays (*f*) abound. Some of these, like that represented near the centre of fig. 23, *f'*, are very large, consisting of a dense mass of vascular and cellular tissue, whilst others (*f*) are of the smaller cellular type common to all the Lepidodendra. The general arrangement of these rays is well shown in the radial longitudinal section (Plate XXVI. fig. 22, *f*), which closely resembles, so far as the rays are concerned, a similar section from a living Conifer. In the figures of *Diploxylon* given by Mr. BINNEY * the woody zone is represented as coming into contact with the medullary vascular ring by a series of concentric curves, the convexities of which are directed inwards. CORDA represents the examples upon which he based his genus in the same way. But the specimens now under consideration do not exhibit this contour, the line of demarcation between the two tissues being nearly straight. The crenulated outline is also represented in WITHAM'S *Anabathra*; but in this instance the irregularity is easily explained. *It does not correspond with the line of demarcation between the two tissues.* I am indebted to the kindness of Professor KING, of Galway, for a very fine transverse section of WITHAM'S original plant, and find that the greater part of its area is broken up into a series of small circles, within each of which the tissues of the plant are well preserved, but external to which there is nothing but agatized mineral matter. The line of junction between the medullary vessels and the ligneous zone is similarly affected. Hence probably the existence in this case of the crenulated outline referred to. WITHAM himself correctly refers these appearances to "the crystallization of siliceous matter" †. At the same time plants of the class under consideration do exist which possess this crenulated inner margin of the ligneous zone. M. BRONGNIART has represented one in his well-known memoir on *Sigillaria elegans*, and I will now call attention to another which presents the best illustration of the structure in question that I have yet seen. It was obtained from the lower coal-measures near Oldham, by Mr. NIELD, and its appearance before being cut into sections is represented in Plate XXIX.

* Description of some Fossil Plants, &c. *loc. cit.* pl. 30. fig. 4.

† The Internal Structures of Fossil Vegetables found in the Carboniferous and Oolitic Deposits of Great Britain, by HENRY T. M. WITHAM, of Lartington, Edinburgh, 1833, p. 40.

fig. 33*. It is of precisely the same type, so far as its general organization is concerned, as Plate XXVIII. fig. 21, consisting of a hollow central cavity surrounded by a ring of medullary vessels (*c*). The line of demarcation between these two tissues is crenulated with great regularity; not only so, but at *c'*, where the ligneous zone has been broken away from the zone of medullary vessels, we see that the exterior of the latter is fluted like the medullary cast of a Calamite, for which the specimen might very easily be mistaken. The more minute details of the transverse section are shown in the enlarged segment of it represented in Plate XXIX. fig. 34. In this figure it will be seen that the woody zone presents the convexities of its outline (*d'*) towards the medullary axis; whilst the vessels of the latter, filling up the angles (*c'*) between the convex projections of the former, are very small compared with those composing the rest of the medullary zone (*c*). The cellular tissue of the medullary rays has disappeared, but the cavities which mark their position are almost identical with those of fig. 21. In both this specimen and that previously described, vascular bundles (*m*) pass outwards to the leaves.

We must now pass to some allied genera of the Lepidodendroid family. One of the most interesting of these is a very small specimen of *Ulodendron*, for which I have been indebted to Mr. Nield, of Oldham. Plate XXVI. fig. 24 represents a transverse section of this stem, magnified two diameters. Plate XXVII. fig. 25 is a longitudinal section of its central axis, enlarged twelve diameters. Plate XXVII. fig. 26 is a transverse section of the same portion, and Plate XXVIII. fig. 27 is a longitudinal section of the outer bark and epidermis, with the bases of its petioles attached.

The structure of the central axis (figs. 25, 26) is identical with that of the *Lepidodendron* represented in figs. 12, 13 & 14. We have at *a* the same vertical piles of cells, devoid of any indication of spiral structure, their transverse septa being, as before, sometimes rectangular and sometimes oblique. The transverse diameter of each of these piles varies from ·0025 to ·005. The cavity (*a'*) in the centre of this medulla is clearly *not* fistular, but a mere rupture, the result of desiccation. Surrounding this is a circle of barred vessels (*c*) with about eight or nine tubes, counting radially; these are not arranged in rows, but represent the medullary vessels of the Lepidodendra. The ligneous zone (figs. 25, 26, *d*) is very feebly represented. A great portion of its circumference has disappeared through disorganization, but it remains at one or two points; nowhere, however, in such measure as to present a lineal arrangement of its small barred vessels. It is chiefly in the longitudinal section that they can be distinguished by their small size. External to the central axis is a large space from which the tissues have wholly disappeared, comprehending most of the inner and middle portions of the bark. Externally we meet with some of the latter in the shape of coarse parenchyma, the cells of which have a diameter of ·003. This passes through an exceedingly narrow layer of common prosenchyma (Plate XXVI. fig. 24 & Plate XXVIII. fig. 27, *i*), but a few cells in thickness, into the tubular prosenchyma (Plate XXVII. fig. 25 & Plate XXVIII.

* I have more recently obtained a second fine example of this species from Mr. James Whittaker, of

fig. 27, *k*) of the subepidermal layer, whilst beyond this again the outermost epidermal parenchyma reappears and composes the bases of the leaves (Plate XXVI. figs. 24 & 27, *l*). These petioles present the usual appearance of such appendages. Plate XXVIII. fig. 28 represents a tangential section of them, close to the surface of the epidermis. The transverse diameter of each cicatrix is fully three times its vertical one; in other respects these petioles are undistinguishable from those of the Lepidodendra already described. Fig. 24, *l'*, shows that the extremities of the petioles are compressed and membranous, whilst their bases (fig. 24, *l*) are turgid. One striking feature of this plant is the great apparent thickness of the mass of persistent petioles, as indicated by the lower portion of fig. 24, all external to the dark line of tubular prosenchyma (*k*) being an aggregation of these appendages. So far as all these portions of its organization are concerned this *Ulodendron* resembles the lowest types of *Lepidodendron.*

The remarkable circular areolæ of *Ulodendron* arranged in two vertical rows, one on each side of the stem, are sufficiently distinct in this specimen; they have each a diameter of more than an inch. But sections through them exhibit no peculiarity of structure beyond the circumstance that, in this specimen, the epidermal layer is absent from their superficial area*. The margin of the band of tubular prosenchyma (*k*) forms their outer boundary line, whilst their superficies is occupied by the middle bark. In one instance I have discovered indications of a vascular bundle running to the centre of the areola, but it is too indistinct to be of much value. It seems probable that these scars sustained objects which were chiefly developed from the epidermal layer, and whose bases rested upon the outer bark; they certainly were not roots or branches, and I incline to the belief that they were organs of fructification.

Amongst numerous other specimens for which I am indebted to Mr. WHITTAKER, of Oldham, is a small but very well-marked fragment of *Favularia*, with the characteristic square cicatrices of full size and remarkably prominent. The specimen had been subjected to great pressure; consequently the subepidermal layers of the two sides had been brought into the closest contact, whilst the central axis, along with detached fragments of the prosenchyma, had been squeezed out from between the contiguous cortical layers. Unfortunately I did not obtain a good transverse section of the medullary axis and ligneous zone, having only discovered their presence by finding them in two of my longitudinal sections. The latter, however, show them with some distinctness. Plate XXVII. fig. 29 exhibits a longitudinal section of three of the epidermal leaf-scars (*l*) with a fragment of the central axis in almost its normal position, the greater part of the cortical prosenchyma, which ought to have intervened between the two, having been forced out of its place. Plate XXVIII. fig. 30 is a transverse section of two of the leaf-scars and the subjacent prosenchyma. Fig. 31 is a radial longitudinal section of one portion of the central axis to the right hand of fig. 29, including part of the medulla, all the ligneous zone, and a little of the cortical parenchyma. Fig. 32 is a longitudinal section of the epidermal layer, showing the transition from the regular paren-

* The specimen has been weathered or watered over; which may possibly account for the absence.

chyma (*l*) of the leaf-bases into the tubular prosenchyma (*k*) adjoining the inner layer of the epiderm.

The medullary axis has been ruptured, leaving a cavity (fig. 29, *a*′) filled with carbonaceous matter; it has consisted of cells (fig. 31, *a*) arranged in somewhat regular vertical piles, many of these cells having a quadrate shape with a diameter of ·005, whilst others of the same form have only about half that diameter. Many others, again, are elongated vertically to a length of ·012. Of the diameter of this axis I have no means of judging, owing to the derangement of these parts of the plant. This axis has been surrounded by a cylinder of barred vessels (figs. 29 & 31, *d*), which may have been disposed in radiating series, though I cannot be quite certain respecting this point; since it is possible that this vascular zone may comprehend both medullary and ligneous vessels, the difference between them being masked by imperfect mineralization. But the opinion that some of them were arranged in a radiating series is further sustained by the circumstance that, in parts of the woody zone, there are straight lines of cells, having a muriform arrangement, but the cells are elongated vertically as in the medullary rays of Calamites. I only meet with these in certain portions of my longitudinal sections; but they look exceedingly like medullary rays, and are of course suggestive of a radial arrangement of the vessels between which they pass outwards. They may, however, belong to the bark. The vessels have a diameter of ·0012; in many of them the transverse bars have disappeared through imperfect mineralization, but in others they are sufficiently distinct to demonstrate their nature. Immediately external to the vascular zone, I discover patches of oblong, fusiform prosenchyma (fig. 31, *g*); but we now come to a hiatus (fig. 29, *h*) from which the tissues have been displaced, but which has been occupied by the middle bark. Small patches of the outer bark appear (fig. 29, *i*′) attached to the inner surface of the epidermal layer. All these patches consist of the same oblong fusiform prosenchyma as that adhering to the exterior of the ligneous zone. Coupling these facts with the additional one that all the numerous detached fragments of bark seen in the specimen consist of beautiful examples of the same tissue of uniform size, unmixed with any other; and arranged in parallel lines with the greatest regularity, I arrive at the conclusion that the entire bark has closely resembled that of the plant indicated by Plate XXV. fig. 8. At the junction of the outer bark (*k*) with the epidermal layer (*l*) we find the usual transition of the fusiform into the tubular form of prosenchyma (Plate XXVIII. fig. 32), which, as is seen in fig. 30, *k*, is still arranged in radiating lines, until it suddenly passes into the parenchyma of the external epiderm and of the bases of the leaves (figs. 30 & 32, *l*). This parenchymatous structure is one of the most regular and beautiful that I have met with. On making a tangential section of the bases of the leaves, we find that they consist entirely of parenchyma, but with a point in the centre of each scar, marking the spot where the vascular bundles penetrated the leaf, and where the parenchyma is much more dense, consisting of much smaller cells than elsewhere. The same conditions exist at the outer surface of each scar or petiole. I have not discovered any traces of the vascular bundles passing from the woody zone to the

epiderm in the longitudinal section, but I find them in the tangential section of the latter tissue.

From the above description it will be obvious that though *Favularia* has its own peculiarities, especially as seen in the varied character of the cells constituting the medullary axis, and in the apparent though not certain absence of all medullary vessels, its general structure indicates its close affinity with the Lepidodendroid plants; we have in both the same thick prosenchymatous bark with its thin tubular layer at the inner surface of the epiderm passing into the regular parenchyma of the petioles. These facts are important because of the obscurity which yet rests upon the history of the true Sigillariæ. No one has questioned the close affinity of *Favularia* and *Sigillaria*: the very prominent cicatrices of the former are but exaggerated representatives of the slightly projecting leaf-scars of the latter.

A remarkable specimen of *Favularia*, which appears to have borne cones, will be described in the sequel of this memoir.

Considering the abundance of Sigillariæ in the Coal-measures, it is marvellous that *indisputable* specimens displaying their internal organization should be so rare; but such is the case. After years of search I have only met with three specimens, of the Sigillarian character of which there can be no doubt. One of these is a portion of the epidermal layer, with five of the parallel flutings that characterize the genus, each of the depressed ridges having a breadth of nearly three eighths of an inch, the distance between the central point of one areola and of that adjoining it being rather more. On the external surface the grooves separating the prominent ridges follow a slightly wavy course, as in the *Sigillaria contracta* of BRONGNIART and several other species; but at the inner surface of the epiderm, where there are corresponding longitudinal projections, the latter are in straight lines, explaining the difference so commonly observed in the Sigillariæ found in the coal-shales between the outer surfaces and the so-called *decorticated* portions; the latter are, as I have already shown to be the case among the true Lepidodendra, casts of the inner surface, not of the bark, but of its epidermal portion, which has been held together by the firm layer of bast-tissue that occupies its inner surface.

The structure of what remains of this specimen is very similar to that of the one last described. Plate XXIX. fig. 35 is a transverse section, enlarged four diameters, of four of the ribs, the outer surfaces of which project into the stone. Fig. 36 represents one of these, magnified thirteen diameters. The external portion (l) consists of very regular parenchyma, which becomes exceedingly dense at its outer surface; but internally these cells assume a radiating linear arrangement, a circumstance to which I shall again call attention when speaking of the structure of *Stigmaria*. Still more internally (i) we have smaller prosenchyma arranged in the usual radiating lines. On turning to the longitudinal sections, Plate XXVIII. figs. 37 & 38, the latter of which is a more highly magnified representation of a portion of the former, we have precisely the outline which a corresponding section of an ordinary *Sigillaria* would present. The depressions (l) in the outline represent the lozenge-shaped scars left by the deciduous petioles, whilst l' are

the sloping surfaces running from the inferior margin of one cicatrix to the base of the upper prominent edge of the next below it. The inner surface of the section exhibits the prosenchymatous layer (*i*), which occupies about one half of the section; part of this prosenchyma consists of cells of the usual fusiform type, whilst other portions are prolonged into tubes, as amongst the Lepidodendra. I found the above specimen amongst the Lower Coal-measures near Oldham.

Though there is no question that the specimen last described is a true *Sigillaria*, it belongs to a type intermediate between the true *Favulariæ* and the *Syringodendra*. But Plate XXIX. fig. 39 represents three of the longitudinal ribs of a true Syringodendroid *Sigillaria*, from a specimen for which I am indebted to Mr. NIELD, of Oldham. The figure is of the natural size. A transverse section of a portion of this specimen, also of the natural size, is seen in fig. 40. Plate XXX. fig. 41 represents a segment of fig. 40, magnified 15 diameters, and Plate XXIX. fig. 42, which is also enlarged 15 diameters, is a radial longitudinal section which passes through part of one of the leaf-scars.

I cannot identify this *Sigillaria* with any of BRONGNIART'S species; but it unmistakably belongs to the group of *S. Saullii*, *Schlotheimii*, and *scutellata*, and of which his *Syringodendron cyclostigma* has merely been a narrow-leaved example.

The transverse section (fig. 41) merely exhibits an external layer of parenchyma (*l*) with an inner one arranged in regular radii, and which consists of an elongated tubular form of prosenchyma (*i*), an arrangement almost identical with that of the corresponding section of *Favularia* (Plate XXVIII. fig. 30). The longitudinal section (Plate XXIX. fig. 42) is much more interesting: at *l* we again have the parenchyma, the cells of which tend to an arrangement in lines which incline upwards and outwards. Immediately below each leaf-scar the cells are purely parenchymatous, but lower down, in the space between two leaf-scars, they become more elongated and fusiform than in the portion figured.

The elongated prosenchyma (*i*) of the inner epiderm and outer bark is very regularly arranged in elongated tubuli; but as the very thin radiating laminæ of these elongated cells do not exactly run parallel with the plane of the section, they are intersected at intervals by lines, *k'*, giving rise to the appearance of medullary rays, an appearance also represented in the corresponding portion of BRONGNIART'S *Sigillaria elegans*. That author describes this tissue as "formé de cellules allongées, très-serrées terminées par des extrémités coupées obliquement, *et dont plusieurs contiguës correspondent à la même hauteur, de manière que leurs terminaisons forment des lignes transversales en zigzag*"*. The last portion of the sentence which I have italicised is, I believe, a mistake. I have no question that, in my specimen at least, the appearance is due to the cause just specified, viz. to a want of exact parallelism between the planes of the radiating laminæ of prosenchyma (seen in the transverse section, fig. 41, *k*) and that of the vertical section. Of course whenever the latter passed obliquely through one of the former, which it does continually, it would cut off a number of tubes in the same line, and give them the

* *Loc. cit.* p. 419.

appearance of terminating at that line, which certainly is not the case*. The arrangement of the parenchymatous and prosenchymatous tissues in this section again corresponds very closely with that seen in the similar one of *Favularia* (fig. 32). But the most instructive part of the specimen is exhibited by the vascular bundle (fig. 42, *m*), consisting of several very minute barred vessels, and obviously surrounded by a thick mass of very delicate cellular tissue, which is parenchymatous, but with a tendency on the part of the cells to become elongated in the direction taken by the vascular bundle. Near the outer surface of the epiderm these cells become merged with the ordinary epidermal parenchyma. Where this cellular mass, in passing through the epiderm, comes in contact with the prosenchyma of the latter (fig. 42, *i*), the tubes of the prosenchyma all bend inwards in the line of the vascular bundle: this is the case in each instance where my sections cross a leaf-scar. It will also be seen from fig. 42, that, at these points, the prosenchymatous tissue projects (*k*) into the subjacent bark.

The entire thickness of this double layer has been fully a quarter of an inch. In the interior of the stone that of the opposite side is also preserved; but every portion of the intervening bark, as well as of the central vascular cylinder and medullary axis, has disappeared. The specimen is in the condition in which all the flattened stems of the Sigillariæ so common in the coal-shales doubtless have been, viz. a mere cylinder of epiderm, rendered tough and resisting decay through its inner layer of elongated fibrous prosenchyma, and having its two opposite inner surfaces brought into near proximity as soon as sufficient pressure was applied to the sides of the stem.

It is a remarkable circumstance that after the publication of the valuable and clearly illustrated observations on the structure of *Stigmaria* made by M. BROGNIART†, there should have been, in later years, so much misapprehension respecting this well-known plant.

The first movement in the wrong direction originated with Professor GOEPPERT, who described a *Stigmaria* ('Genres des Plantes Fossiles,' tab. 13) with vascular bundles passing longitudinally through the pith, and from which he believed the vascular bundles going to the rootlets were supplied. In this he was followed by Dr. HOOKER (Memoirs of the Geological Survey of 'Great Britain),' who clearly affirmed the existence of medullary rays and bundles, but adopted GOEPPERT's idea as to their origin. At this stage of the inquiry a very fine pyritized specimen came into my possession, a figure of which was given by Mr. BINNEY in the 'Quarterly Journal of the Geological Society of London' (vol. xv. pl. iv. fig. 1, *a*). This specimen, and others subsequently found by Mr. BINNEY, made it clear that the woody axis had been surrounded by a thick, but as yet unknown

* The mistake is mine. I have more recently obtained evidence that, even in my specimens, these long, parallel-sided cells are bounded at their extremities by the horizontal lines, *k'*, as described by the French botanist.—May 5, 1872.

† "Observations sur la structure interne du *Sigillaria elegans* comparée à celle des *Lepidodendron* et des *Stigmaria* et à celle des végétaux vivants. Par M. ADOLPHE BRONGNIART," Extrait des Archives du Muséum d'Histoire Naturelle, tab. 5. figs. 6, 7, & 8.

bark. In the memoir just referred to*, Mr. BINNEY recognizes the medullary rays, but again adopts GOEPPERT'S explanation of the origin of the vascular rootlet-bundles, and gives a figure of a specimen which he supposed afforded confirmation of this explanation, having ten or twelve large vessels, as he believed, in the pith, "each of about one tenth of an inch in diameter." The largest vessels which I have seen in the woody stems of *Stigmaria* do not exceed ·005 in diameter, whilst those going to the rootlets are generally much smaller. I have elsewhere called attention to the way in which the rootlets of *Stigmaria* have penetrated every thing within their reach that was penetrable; and I have no doubt that in both Professor GOEPPERT'S and Mr. BINNEY'S specimens, these supposed medullary vessels were really Stigmarian rootlets that had found their way into the interior of the cavity left by the decay of the medulla, and been mistaken for a part of the plant into which they had intruded themselves†. Mr. BINNEY, in 1857, discovered the structure of the rootlet of *Stigmaria*, and also gave the first insight into the nature of the outer bark. In some specimens supplied to him by Mr. RUSSELL, of Airdrie, he found remains of an outer radiating cylinder, at a considerable distance from the inner one, and upon which the rootlets were planted. This outer cylinder Mr. BINNEY described as consisting of "wedge-shaped masses of tubes or elongated utricles"‡. With this discovery progress virtually ceased. The subsequent history has mainly been one of retrogression. Notwithstanding the clear statements of HOOKER, and the equally accurate figures of BRONGNIART, it has become the fashion to deny the presence of medullary rays in *Stigmaria*. This has been done on several occasions by my friend and fellow labourer in this field of research, Mr. CARRUTHERS; but I think I shall be able to demonstrate that, for once, his usually accurate powers of observations have failed him, owing partly to his not having seen the best specimens, and partly to his general objection to the recognition of medullary rays in the stems of these Palæozoic Cryptogams. Mr. CARRUTHERS states that he has met with one specimen in which the central axis exhibits elongated scalariform cells. Not one of my numerous specimens contains a trace of any such structure. I speak with hesitation as to the cells of the *central* part of the medulla, because even when present these cells are almost always disintegrated; but so far as the more peripheral ones of the pith of the true *Stigmaria* were concerned, I have the clearest proofs that they never were barred.

I am convinced that one cause of the discrepancies that exist amongst writers on this subject has been the want of an exact definition of a *Stigmaria*, several very distinct roots having been included in the term. But the plants described by BRONGNIART,

* Some observations on *Stigmaria* (*loc. cit.* pl. iv. fig. 2).

† I have before me at the present moment a section of a large *Lepidodendron* of which the woody axis and its medullary centre have disappeared, the thick cortical layer alone remaining. A large Stigmarian *root* has found its way into the cavity and filled it up, giving off its peculiar rootlets within the Lepidodendroid cylinder. Such a specimen would inevitably mislead even a botanist, whose eye was not familiar with the appearances of the two plants.

‡ Philosophical Transactions, 1865, p. 593 and woodcut 4.

HOOKER, and BINNEY have such distinctive features that they ought not to be mistaken for any other. I shall now proceed to show what those features are. I must add that for some of the most remarkable specimens which have enabled me to throw additional light upon this subject, I have been indebted to Messrs. NIELD and WHITTAKER, of Oldham. Others have either been furnished by Mr. BUTTERWORTH, or found by myself. Of the figures accompanying this memoir, Plate XXX. fig. 43 is a portion of a longitudinal radial section of a part of the woody cylinder at its *inner* or medullary surface. In this figure, *n* is a vascular bundle passing outwards through a large medullary ray. Plate XXIX. fig. 44 is a corresponding section of the *outer* part of a similar cylinder. Plate XXIX. fig. 45 is a tangential section from the interior of the woody cylinder, revealing one large or *primary*, and numerous smaller or *secondary* medullary rays. Fig. 46 is a still more enlarged section of part of fig. 45, with two vessels and several secondary medullary rays. Plate XXX. fig. 47 is a transverse section of part of the medullary or inner portion of the woody axis, with a primary medullary ray and a vascular bundle going off to one of the rootlets. Fig. 48 is part of the external surface of the ligneous cylinder. Fig. 51 is a transverse section of part of the epiderm with the attached bases of three rootlets. Plate XXXI. fig. 52 is a further enlargement of another rootlet with the epidermal layer from which it springs, and fig. 53 is a diagrammatic restoration of the entire plant. Each of these structures requires to be examined in detail.

Several of the specimens which I have examined exhibit more or less of the medullary axis, especially one given me by Mr. WHITTAKER, of Oldham. It consists of delicate parenchyma, which is better preserved where it is in contact with the ligneous zone (Plate XXX. figs. 43 & 47, *a*) than in the more central portions, where it has been more liable to become disorganized from some unknown cause. The cells have a diameter of from ·005 to ·0025. There is not a trace of any spiral or barred structure in the cell-walls, nor of any medullary vessels such as are common in many of the Lepidodendroid stems.

The woody zone consists, as is well known, of a cylinder of radiating wedges which increase in size from within outwards. These wedges are composed of large barred vessels arranged in radiating lines, and in the most regular order. The external surface of the zone, as seen in one of Mr. WHITTAKER's fine specimens, is represented in Plate XXX. fig. 48, which exhibits a disposition of the structures recurring in every tangential section made from any part of the woody cylinder, and which disposition is one essential characteristic of a true *Stigmaria*. The woody wedges (fig. 48, *e*) alternately approximate and diverge, leaving, in the latter case, large lenticular spaces (*f'*) filled with muriform cellular tissue passing straight through the entire ligneous zone, and which are the medullary rays of BRONGNIART and HOOKER. The vessels (*e*) have a diameter which varies from ·0025 to ·005. On making a tangential section like Plate XXIX. fig. 45, we see that the lenticular orifice is a large medullary ray (*f'*), which may be distinguished by the name of *primary*. It consists, as seen in the section,

of ordinary but very delicate parenchyma, which gradually thins out, upwards and downwards, into a single interrupted row of cells. This latter part connects these larger medullary rays with a multitude of smaller or secondary ones (f) seen in the same section. Sometimes these consist only of one single cell: more frequently we see two or more arranged in a single vertical series; and from time to time still larger ones occur with two or even more parallel vertical rows of these cells, thus approximating their arrangement to that of the primary rays. The cell-walls of these secondary medullary rays are so exceedingly delicate and thin that it is not easy to trace them through the radial longitudinal sections of the ligneous axis; nevertheless careful manipulation of the light enables the observer to do so. At their inner or medullary extremity all these rays, primary and secondary, take their rise in, or rather are merely prolongations of the cellular medulla, the parenchymatous cells of the latter (Plate XXX. figs. 43–47, *a*) being unaltered in shape or arrangement in the immediate neighbourhood of these radial prolongations of the pith; but on entering the medullary ray they soon become mural, being elongated in the direction of the ray. This elongation is seen equally in transverse sections (fig. 47, f') and in radial ones (Plate XXX. fig. 43, f', & Plate XXIX. fig. 44, f'). At their outer extremities (fig. 44, g') they merge in a corresponding manner in a delicate cellular tissue (fig. 44, g), which constitutes the innermost layer of the bark.

We see in the transverse sections of the woody cylinder very clear evidences of successive and interrupted exogenous growths. At each of these lines the continuity of the radiating lines of vessels becomes wholly interrupted and a new series commences. These new vessels are at first very small and irregularly disposed, but, as we proceed outwards, they soon resume their regular arrangement and size. In one of my sections I have clear evidence of a new circle of these small and irregularly disposed vessels forming externally to the entire cylinder, as if in a cambium layer. These additional layers are not always added equally to the entire circumference of the *Stigmaria*; they sometimes only surround some two thirds of that circumference, as is not unusual amongst living Exogens. But the most remarkable feature of the woody zone is supplied by the vascular bundles given off to the rootlets, and which reach them exclusively through the primary medullary rays. On making a tangential section of any portion of the woody cylinder, we discover appearances which are virtually repetitions of what is seen in Plate XXX. fig. 48, the latter being merely the external surface of the ligneous zone, which exhibits the same arrangement of tissues in all sections made parallel to that surface. The bundles of vessels (e), which are really the external surfaces of the radiating woody wedges seen in the transverse sections, alternately separate and reunite, leaving the large lenticular areas (f') constituting the primary medullary rays already described. As one of these rays proceeds outwards, the vessels bounding its sides at the upper angle detach themselves from the wedges to which they severally belong, and combine to form what, in the tangential sections, appears as a tongue-like projection hanging down (Plate XXIX. fig. 45, n, & Plate XXX. fig. 48, n) into the ray. A radial

section made in the plane of this tongue, shows us that the vessels composing it are deflected outwards (Plate XXX. fig. 43, n') at right angles to their previous course. In the section fig. 43 the cells of the part of the medullary ray bounding the remoter side of this mass of deflected vessels are seen at f''. Fig. 47 is an oblique transverse section passing through the inferior keel-like edge (n) of this vascular mass at the innermost part of its course, and exhibiting the derivation of its component tissues from the two vascular wedges (e, e) bounding the medullary ray through which it ploughs its way outwards. Plate XXIX. fig. 44 is a radial section from the external portion of the ligneous cylinder, where we still find even the outermost of the vessels (e) contributing their share to this vascular root-bundle (n), the letters f in this section indicating the external portion of the medullary ray just previous to its becoming merged with the inner bark (g). It follows that an enormous number of the vessels directly vertical and superior to each primary medullary ray have their lower extremities bent outwards; but when we examine the ultimate bundles (Plate XXXI. fig. 52, n') that leave the exterior of the woody cylinder and pass through the bark to the rootlets, we find that the number of vessels composing them is very limited, rarely reaching twenty. Hence it is evident that the greater part of the deflected tubes never reach the rootlets, but successively disappear in the tongue-like projections seen in Plate XXIX. fig. 44, n, & Plate XXX. fig. 43, n.

With the exception of the portion of the exterior noticed by Mr. BINNEY, the cortical layer of *Stigmaria* has not yet been described; but a series of specimens in my cabinet, and in those of my coadjutors, enable me to fill up this hiatus in the history of the plant.

I have already pointed out that the exterior of the ligneous cylinder is invested by a thin layer of very delicate cellular tissue (fig. 44, g), the cells of which are somewhat elongated vertically (Plate XXX. fig. 49, g)*. In other respects they are almost identical with those of the pith, and wholly so with those of the medullary rays, save in the direction of their longer axes. In a large majority of the examples which I have seen this tissue is the only representative of the bark that is preserved; but I have several specimens which, when combined, give me its entire substance. The thin layer of delicate cells seen in fig. 49, which is not above ·015 in thickness, soon passes into a thin stratum of equally delicate parenchyma, which in its turn passes into a very thick layer consisting of an irregular and variable mixture of prosenchyma and parenchyma, but principally the former. In transverse sections these tissues are seen arranged in very narrow but regular radiating lines, each of which usually has a breadth of about ·00085. The appearance in this section is that of a coniferous wood with very delicate fibres; but on making either a radial or a tangential section, the tissues forming this part of the bark usually appear as represented in Plate XXXI. fig. 50. It will be seen from this figure that whilst some of the cells have pointed and overlapping extremities, others have slightly oblique, and others, again, square ends. The tissue has evidently

* It is impossible to overlook the close resemblance which this tissue bears to that seen investing the vascular bundles of the living Lycopods, and to which NÄGELI and SACHS have given the appropriate name of procambium. —May 6, 1872.

been prosenchymatous in its general character, but of a very corky form. This is not only shown by the large amount of parenchyma which enters into it, but also in its extreme liability to compression. In one of my specimens this compression from without has given the transverse section an appearance of numerous concentric bands arranged parallel with the surface of the ligneous zone; an appearance which puzzled me the more, since this was the first example in which I found the entire bark. Other examples subsequently coming into my hand threw light upon the perplexing arrangement. Numerous little apertures exist in this bark, through which, I doubt not, the vascular bundles passed to reach the rootlets.

The portion of the bark which is most frequently preserved is the epidermal layer, the structure of which is interesting because of its relation to that of the rootlets long since described by Mr. BINNEY. Plate XXX. fig. 51 represents a transverse section of this epiderm with the bases of three of the rootlets implanted in it, whilst Plate XXXI. fig. 52 represents the same tissue yet further enlarged, from another specimen lent to me by Mr. BOYD DAWKINS. As will be seen from the latter figure, the epiderm consists of a very regular form of thick-walled parenchyma (*l*), the cells of which become very much smaller and more dense as they approach the outer surface. Internally this parenchymatous layer is continuous with a more delicate one (*k'*) of the same character but with thinner cell-walls, and the cells of which soon become vertically elongated and arrange themselves in straight lines radiating inwards, as in *Sigillaria*. This is doubtless the radiating cylinder seen by Mr. BINNEY in Mr. RUSSELL'S specimens previously referred to, only instead of being arranged in wedge-shaped masses, as represented by Mr. BINNEY, a result of the imperfection of his specimen, it is a perfectly continuous layer, and doubtless represents the exterior of the bast-layer of the Lepidodendroid type. The thickness of this outer bark is unequal, in consequence of the depressions (Plate XXXI. fig. 53, *p*) that receive the proximal extremities of the rootlets, whose bottle-like bases, when perfect, as in fig. 51, *o'*, are implanted in concave depressions of unequal depths, displacing both parenchyma and prosenchyma. The external cellular cylinder of the rootlet (*o*) is merely an extension of the thick-walled outer epiderm *k*, and is not in any way articulated to the prosenchymatous tissue. Within this is a space (Plate XXX. fig. 51, *o'*, & Plate XXXI. 52, *o'*) in which I have never seen the tissue preserved in rootlets which could be proved to be Stigmarian. Myriads of rootlets exist in the calcareous nodules from which our Lancashire specimens are obtained, of which all the cellular structures are preserved from their central vascular bundle to their periphery; but these, I am convinced, belong to other plants than that under consideration. In the centre of the vacant space we have the vascular bundle (*n*), which, though always intersected in some part of the section, can rarely be traced far in one plane because of the flexures of the rootlets. The central axis of about twenty barred vessels is always surrounded by a thin cylinder of delicate cellular tissue. Wherever we see these vascular bundles in the bark between the woody cylinder of Stigmariæ and the epiderm, we invariably find this cellular ring surrounding the vessels, as at fig. 52, *n'*; it is continuous with

the innermost bark and with the cells of the primary medullary ray through which the bundle emerged. It appears at fig. 51, n'', where the bundle is entering the rootlet, and it equally reappears if we intersect the latter at its extreme tip. The epidermal tissues immediately subjacent to each rootlet are always dense, consisting of small parenchymatous cells, which show a tendency to arrange themselves in radial lines (fig. 51, k). When the vascular bundles are intersected between the woody zone and the epidermal layer, their outline is usually that of a triangle with convex sides, as seen at fig. 52, n'. Plate XXXI. fig. 53 is a restored diagram, exhibiting what I believe to have been the structure and form of *Stigmaria* in its integrity. The several parts of this diagram will be easily identified with the details of the preceding description, because the same letters have been employed in both to represent corresponding tissues.

I have frequently found in the Lower Coal-measures at Oldham fragments of a very curious bark that long perplexed me, because I was unable to discover it in association with any woody axis. In one example it appeared partially to surround a *Diploxylon*; but as the portion on one side of the ligneous cylinder appeared to be in a reversed position to that on the other side, I both hesitated to connect them and was unable to decide which was the inner and which the outer surface of the bark. On cutting vertically through a part of the specimen represented in Plate XXVIII. fig. 33, and which is essentially a *Diploxylon*, I again found the anomalous bark associated with this type of ligneous cylinder, and under such circumstances as left me little room to doubt that it belonged to the same plant. The general appearance of these fragments, when cut transversely, is shown in Plate XXXI. fig. 54. Spaces of a lenticular form (h) radiate towards the periphery*; these are filled with cells, whose parallel sides cross the short axis of each space. The long axis of each cell is often as much as ·0075 in length and ·005 in the opposite direction. At one extremity these lenticular masses show a disposition to converge at irregular projecting points; at the other they gradually pass into regularly disposed lines of narrow prosenchyma (h'). The lenticular masses of cells exhibit nearly the same appearance in the radial section that they do in the transverse one; but a tangential section exhibits the cells in fasciculi (fig. 56), where small clusters of them are seen enclosed within dark and strongly defined areas of a doubtful nature. In the regularly arranged prosenchymatous portions the tangential and radial sections are very different from the transverse ones, and, indeed, they vary in different specimens. Fig. 55 is a radial section of a strongly marked type, in which the prosenchymatous cells appear to be of nearly equal lengths and with square ends, so much so, indeed, as to resemble some varieties of mural tissue common amongst the Calamites; but in the tangential section (fig. 56) we see that they are prosenchymatous, but of a very sharply defined geometric type, with straight walls and very distinct angles. But in many other speci-

* I have just met with an example of Stigmarian bark, with its characteristic rootlet attached, in which the structure represented in fig. 54, h, occurs, intermediate in position between the outermost parenchyma and the more internal radiating prosenchymatous layer, blending the two: whether it is merely a variety, or belongs to the Stigmarian root of some distinct species of Lepidodendroid plant, has yet to be ascertained.—Aug. 6th, 1872.

mens which I have dissected, this geometric character is less obvious, the prosenchyma assuming in them the aspect so common in the bark of *Stigmaria*. On a fragment of the specimen fig. 33 there are indications that the bark has been very thick*, and that the portion represented by fig. 54, *n*, has not been far removed from the woody cylinder, though not being actually the innermost bark. The more external parts consist of radially arranged prosenchyma, but with an appearance of a second row of lenticular masses of large cells external to, and of smaller size than, that first described. I have noticed an approach to all these peculiar arrangements in some specimens of the bark of the common *Stigmaria*, which has evidently varied in the details of its structure, the variations possibly representing different genera and species of Lepidodendroid and Sigillarian plants.

The only specimen which remains to be described is a very important one which I discovered in the cabinet of Mr. NIELD. It is a cast or impression of the outer surface of a *Favularia* (Plate XXXI. fig. 58), of a very strongly marked type and with very prominent leaf-scars. But its value consists in the exhibition of a transversely disposed verticil of lozenge-shaped scars (fig. 58, *r*) of a very remarkable character. The figure is enlarged to double the size of the original, in which, being a cast, what are now prominences represent corresponding depressions on the surface of the original bark. The centre of each lozenge-shaped disk consists of a small but prominent circular area; this is surrounded by a ring of much smaller tubercles. Each disk is located at a point where the vertical continuity of the lines of leaf-scars, always so regular in ordinary specimens, is broken, those below the disks being arranged in an alternating series with those above them. It is evident that we have here an hitherto undescribed feature in *Favularia*; but, on discovering the specimen, it occurred to me that I had frequently observed, in the ordinary examples of the so-called "decorticated" *Favulariæ*, transverse bands crossing the stems, along which the regularity of the leaf-scars was interfered with and their distinctness blurred. BRONGNIART has represented a specimen of this kind in tab. 155 of his 'Histoire des Végétaux Fossiles,' though in his plate the break in the continuous lines of leaf-scars is less marked than is often the case. On examining the *Favulariæ* in my cabinet, I found one in which the subepidermal surface displayed the same interruption, but over a part of which there remained the usual layer of coal representing the superficial tissues. On the exterior of the latter I found several scars similar to those of fig. 58. I think there can but be one conclusion respecting these cicatrices. They did not bear leaves, because these are represented by the usual scars above and below them. They are much too small for ordinary branches, besides which, verticils of branches are unknown things amongst these Sigillarian and Lepidodendroid plants. I conclude, therefore, that they supported a row of cones. Now it so happens that one of

* I have more recently met with another example in which the outer prosenchymatous structure was nearly $1\frac{1}{2}$ inch thick; it was of the type containing a mixture of ordinary and fusiform cells, the latter elongated vertically and having a length of about ·015. The arrangement exhibited irregularly alternating concentric layers of prosenchyma and parenchyma, the one gradually passing into the other.

the most common of the Lepidodendroid strobili in the Lower Coal-measures of Oldham is a small one, of the central axis of which I have given a representation in fig. 59, enlarged two diameters, or in the same proportion as fig. 58. Of course I cannot affirm that the two are actually portions of the same plant; but it is enough for my present purpose to indicate the possibility of such a relation. The correspondences of size, the similar central area in each, and the vascular ring surrounding that area present coincidences too striking to be overlooked.

It will have been observed that I have said nothing about that remarkable form of Lepidodendroid plant, the *Halonia.* The fact is, I have not been able to obtain specimens throwing any light upon this subject beyond what has already been done by Mr. DAWES. His figure and description, given in the Proceedings of the Geological Society of London for March 22, 1848, are so clear that there can be no difficulty in locating the plant in its proper place. The central axis consists of cells arranged as in my Plate XXVI. fig. 13, Plate XXV. fig. 14, & Plate XXVII. fig. 25, this is surrounded by a cylinder of barred vessels, as in fig. 13, from the outer surface of which the vascular bundles going to the bark are given off.

The late Mr. JAMES WILDE, of Oldham, published a notice in the 'Geologist' for 1863, p. 266, in which he states that a specimen of *Lepidodendron* with an *Halonia* attached settles in the affirmative the question whether or not the latter is the root of the former. Through the kindness of Mr. NIELD, in whose cabinet the specimen now is, I have had the opportunity of examining it, and conclude that it does no such thing; it merely shows, what we knew before, that *Halonia* is part of a Lepidodendroid plant.

A fragment of an *Halonia* furnished to Mr. DAWKINS by Mr. WHITTAKER, of Oldham, shows that the projecting tubercles which characterize *Halonia* are of the same nature as the scars of *Ulodendron* which I have already described, viz. that they consist of the outer bark which has here pushed up into the epidermal layer, the latter being deflected along their sides. I have little doubt but that the *Halonia* was a fruit-bearing branch of a *Lepidodendron*, and that from each of the tubercles there was suspended a cone*.

* Since the above was written, I have obtained a considerable amount of information on this subject. Two fine specimens in the Museum of the Manchester Geological Society, not only throw light upon the condition just described, but also upon the relations of *Halonia* and *Ulodendron*. One of these specimens is a fine *Halonia regularis*, of the usual type, but which is further invested with a thick bark, showing that the examples of this plant so commonly seen are semidecorticated ones, and that the characteristic tuberculated surface is not the outermost one. I may premise that my more recent investigations have compelled me to alter some of the terms applied in this memoir to the several parts of the bark, in order to bring them into harmony with what I find in recent Lycopodiaceæ; consequently in a third memoir, recently laid before the Royal Society, I have designated the middle bark (*h*) of this paper the parenchymatous layer. The outer bark (*i* and *k*) I have termed the prosenchymatous layer, and what I have called the epidermal (*l*), I now designate the subepidermal layer. The detailed reasons for employing these terms will be given in the memoir referred to, meanwhile they may be applied to the specimens under consideration. In the new *Halonia*, the conical mammilliform tubercles evidently projected entirely through the prosenchymatous layer, and through a great part of the subepidermal one, a thin expansion of the latter alone appearing to invest the apex of the tubercle; and even here there is a small central mucro which exhibits every indication that it accompanied something which projected entirely

Having thus reviewed all the principal facts that have come under my personal observation, and I have almost entirely confined myself to such, it now remains to be seen what general conclusions can be drawn from them. We began with a Lepidodendroid plant, *L. selaginoides*, in which we found the medullary axis largely occupied by a great number of scalariform vessels; but we saw that these were not arranged in radiating order, neither did they give off any vascular bundles to the leaves. These bundles were confined to the inner surface of a very narrow, but nevertheless distinct, enclosing circle of somewhat smaller vessels, between which, and passing radially outwards, were vertically disposed rows of cells, which I believe to be true representatives of medullary rays, whilst the thin cylinder through which they pass is the woody zone separating medullary from cortical structures. The bark we found to be thick, consisting of varying elements of parenchyma and prosenchyma, but chiefly the latter; and near the outer surface we discovered a layer of prosenchyma, where the cells are so elon-

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through the bark, being, in fact, an investure of the vascular tissue accompanying the latter to whatever organism the tubercle helped to sustain.

It thus appears that these outer layers of bark, having an aggregate thickness of from three eighths to half an inch, filled up the deep valleys separating the conical hillocks of the *Halonia*, and almost reduced the entire surface of the plant, when living, to a uniform level. These determinations bring the minute and geometrically arranged punctations covering the surface of the *Halonia* into homological relations with similar markings seen on other semidecorticated Lepidodendroid plants.

The other specimen to which I have referred is a very large example of one of the round or oval scars so characteristic of *Ulodendron*, but which, instead of being more or less depressed, as is commonly the case, stands out as a projecting cone at least 3 inches above the semidecorticated surface from which it rises. If this cone represents, in *Ulodendron*, the mammillary protuberance of *Halonia* (and that it does so I entertain no doubt), its height gives us a measure of the extreme thickness of the prosenchymatous and subepidermal layers of the plant to which it belonged.

The above specimens having again drawn my attention to *Halonia*, I gladly availed myself of some specimens collected and placed in my hands by my friend W. Boyd Dawkins, Esq. On making sections of these I discovered that the vascular axis consisted of a very distinct vascular medullary cylinder enclosing a well-marked cellular medulla; there was no exogenous zone around the cylinder, but in its place a circle of remarkably numerous and closely disposed vascular bu[illegible] a groove in the exterior of the medullary cylinder, and which in the [illegible] the corresponding section of the bundle in its concavity. The cortical tissue consisted of the parenchymatous layer (h), with here and there slight traces of the more external prosenchymatous one (i), the remaining tissues having disappeared.

It is thus clear that, as I have already suggested, the specimens of *Halonia* with which collectors are familiar are branches which have lost the two outer layers of their bark. It is also obvious that the structure of *Halonia* and that of the branch represented in Plate XXVI. fig. 24 are identical; only in the latter specimen the exterior of the vascular medullary cylinder is not quite perfect, since throughout the greater part of it the external indentations with their enclosed vascular bundles have almost all disappeared. A few, however, remain showing that they were originally present, as in my sections of *Halonia*. On the other hand, fig. 24 & Plate XXVII. fig. 25 exhibit the prosenchymatous and subepidermal layers of the bark, which are deficient in Mr. Dawkins's specimen.

Still more recently specimens of the greatest importance, and of most exquisite beauty, have been supplied to me by Mr. Whittaker. From these I can easily make out almost the entire structure of the stem of *Halonia*. The cellular pith and investing medullary cylinder are arranged in our new examples as already described. The vascular foliar bundles appear as in Mr. Dawkins's specimen; but we further learn from them the exact

ated as to constitute a distinct bast-layer, which has exhibited a constant tendency to eparate itself from the other subjacent cortical tissues. Outside this bast-layer we have he superficial epidermis, consisting of thick-walled parenchyma, which also constitutes he tissue composing the bases of the leaves.

These arrangements are repeated with variations of detail throughout the entire epidodendroid series. In Mr. BINNEY'S *Sigillaria vascularis* (Plate XXV. fig. 8) we nd the vascular part of the medullary axis retreating towards its periphery, but with an ndefined inner margin. In *Diploxylon* there is reason to believe that it had become ltogether peripheral, and had a sharply defined inner boundary line, though this latter act cannot be absolutely affirmed until a specimen is found with the whole of the nedullary tissues preserved. In the same two plants we find a corresponding advance n the thickness of the radiating woody cylinder and in the development of the medullary ays. The other genera allied to *Lepidodendron* exhibit structures of the same type. In

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tructure of the entire bark, as well as some other important points in their history. Immediately surrounding he medullary vascular cylinder is a layer of delicate parenchyma, the cells of which average about ·166 in liameter; these cells are arranged in columns which proceed obliquely upwards and outwards, diverging from he perpendicular at an angle of about 35°. The entire thickness of this innermost parenchyma is about the ighth of an inch (·125). Externally to it is the ordinary coarser parenchymatous layer, invested in its turn by he prosenchymatous one, which again is enclosed in what I have recently designated the subepidermal parenhyma. Thus we here see distinctly exhibited the four layers of bark of which I have spoken in other parts of his memoir. The ordinary foliar vascular bundles, given off in great numbers from the outer surface of the nedullary vascular cylinder, ascend upwards and outwards at the same angle as the cells just referred to (35°), ntil they reach the exterior boundary of the innermost parenchyma, when they suddenly bend outwards in a orizontal direction, describing a slight curve as they do so, the concavity of which is directed upwards. Each vascular bundle is invested with a delicate cellular sheath, which is a prolongation of the innermost arenchyma of the bark.

But in addition to these bundles, I have now obtained the larger ones, which proceed to the tubercles characeristic of *Halonia*, and which are very different from the ordinary foliar ones. In the first place, the former are ery much larger, consisting of many more vessels than is the case with the latter; they are accompanied in heir outward course by a yet thicker investment of the cells of the inner bark-layer. But the most remarkable lifference is seen at their point of departure from the vascular medullary cylinder: they are not merely derived, ike the foliar bundles, from the exterior of that cylinder, *but the entire mass of the vessels of the latter, immediately below the bundle, are absorbed into it.* The consequence is that directly above the bundle there is a slit n the medullary cylinder unprovided with vessels, and where the parenchyma of the pith and that of the innernost bark blend their cells into a continuous tissue. This slit ascends for some little distance up the stem, but he vessels on each side of it gradually converge and ultimately close it up. These peculiarities in the origin f the vascular bundle in question appear to me to be of great physiological importance; they can only be nderstood when compared with conditions connected with the branching of Lepidodendroid plants that I have escribed in the third memoir of this series read to the Royal Society on the 7th of March last. I there showed hat, prior to dividing into two branches, the vascular cylinder split into two halves, bringing the cells of the ith and of the bark into direct contact. It is evident to me that the arrangements in the *Halonia* just described re of the same nature, only instead of half the entire cylinder being split off, but a small portion of it is so sepaated. I infer, therefore, that the vascular bundle, thus originated, proceeded to some modification of a branch —but which modification was of smaller dimensions than branches usually attained to, and which, consequently, equired a less abundant supply of vascular tissue than ordinary branches needed. Such a modification would,

Ulodendron the innermost surface of the vascular ligneous cylinder is present, though very small compared with the large medullary one, approximating very closely, in this respect, to the *Lepidodendron* represented in Plate XXVI. fig. 13, Plate XXV. fig. 14. Not having a transverse section of the central axis of *Favularia* (Plate XXVIII. fig. 31), I cannot be certain about its details; but we have in the longitudinal section evidence of a vascular mass, though whether it be medullary or ligneous I am not able to affirm; but BRONGNIART'S *Sigillaria elegans*, which is a true *Favularia*, demonstrates the close resemblance which its central axis bears to that of a *Diploxylon*. Wherever we are able to trace the origin of the vascular bundles going to the leaves, in *Diploxylon*, we

I imagine, only be found in a strobilus, which must be regarded as a branch that has undergone an arrested development at a very early stage of its growth.

Guided by these new observations, I have reexamined the curious specimen found by the late Mr. JAMES WILDE and referred to on p. 222. This is a semidecorticated branch of an ordinary *Lepidodendron*, having a diameter, as it appears in its stony matrix, of about $2\frac{1}{2}$ inches. This stem divides into two smaller branches, one of which is also that of an ordinary *Lepidodendron*; the other displays the same Lepidodendroid features on its upper half, but what constituted its underside, when a growing plant, exhibits rows of the characteristic tubercles of *Halonia*. We here learn two things:—First, that *Halonia belongs to the upper branches* of a Lepidodendroid tree, consequently it cannot be a root. This may be regarded as finally settled. The same truth is demonstrated by Mr. WHITTAKER'S specimens: in these the large vascular bundle going to each tubercle bends upwards and outwards in the same way as the foliar bundles with which it intermingles. This fact alone would be a conclusive one against the root hypothesis. Secondly, we learn that *Halonia* is a specialized branch of a Lepidodendroid tree that is not itself an *Halonia*; and as I have already given reasons for believing that each tubercle sustained an abortive branch, it appears to me that we are shut up to the conclusion that these arrested developments could only exist in the form of strobili.

I think there can be little doubt that the innermost cortical layer, prolongations of which invest *all* the vascular bundles proceeding from the medullary vascular sheath to the periphery, must be regarded as the homologue of what SACHS, following NÄGELI and LEITGEB, has termed the procambian layer in living Lycopods, and which, as we shall see, reappears in *Stigmaria*.

The important truth demonstrated by the specimen in the Manchester Museum, and one with which all the other specimens that I have mentioned appear to harmonize, is, that the projecting tubercles of *Halonia* and *Ulodendron* were confined to the inner prosenchyma of the bark, of which they were conical extensions surrounding and accompanying a fibro-vascular bundle on its way outwards to the surface, but that they did not appear in any marked form, if at all, save as a scar, on the exterior of the plant. No such tubercular provision was made for the very numerous leaf-bundles, and we have abounding proofs that the tubercles had nothing to do with the ordinary branches of the plant. It appears to me that nothing remains with which we can associate them but strobili, and with these I believe them to have been connected. Every new fact that we discover appears to me to bring the two genera *Halonia* and *Ulodendron* into nearer relationship than has hitherto been recognized. I have very little doubt that the *Haloniæ* were young branches sustaining rows of cones: after the cones fell off, they would leave permanent cicatriculæ impressed upon the bark, and which would enlarge as the stems increased in magnitude, the latter process being probably accompanied by the development of an exogenous zone around the medullary cylinder. Specimens of these old and matured fruiting stems may exist among what we have hitherto termed *Ulodendra*. This explanation would give us the reason why we never find cones or other appendages of a magnitude corresponding with the cicatricula of *Ulodendron*. The chief argument against the idea that the cicatriculæ of *Ulodendron* may be those of *Haloniæ* enlarged by age and growth, lies in the fact that the leaf-scars of *Ulodendron* do not appear to have undergone any corresponding enlargement.—April 15, 1872.

invariably find that they proceed from the inner surface of the outer or ligneous cylinder, and not from the larger vessels of the medullary one, and it is in the same radiating cylinder that we find the medullary rays*. I have already stated my reasons for insisting upon the recognition of the medullary character of these rays, and pointed out the necessity for considering their primary origin in the nascent structure, prior to any material differentiation occurring in its tissues, if we are to arrive at a philosophical opinion respecting their nature. All these circumstances combined lead me to the conclusion that in the radiating vascular cylinder we have the representative of the woody zone of exogenous plants. This zone is at its minimum of development in such Lepidodendra as Plate XXIV. fig. 1 & Plate XXVI. fig. 13, whilst it attains to a maximum in some of the Diploxylons, the former bearing some such relation to the latter as the half-developed woody zone of a Cycad does to that of a hard-wooded *Pinus* or *Araucaria*. This opinion receives further support from the unmistakably exogenous growth of this zone. The radiating arrangement of its vessels is suggestive of the conclusion; but we can further see, in many of the stems, clear evidences of interruptions to growth succeeded by periods of renewed vital activity. If this reasoning is sound and the conclusion arrived at correct, the latter gives us an unmistakable clue to the remaining tissues. The thick parenchymatous and prosenchymatous structure investing the woody zone is clearly a bark, although not, it is true, divisible into the three layers of epiphlœum, mesophlœum, and endophlœum; but in the enormous development of elongated prosenchymatous fibres or bast-tissues in the inner layer of the epidermis, we have a manifest foreshadowing of that prevalence of the same tissue in the bark of living Exogens. M. Brongniart has already called attention to the close resemblance which the thick cylinder of medullary vessels found in his fragment of *Sigillaria elegans* bore to the ordinary medullary sheath of an Exogen, and I cannot resist the conclusion that these are homologous structures. It appears to me that these specimens of fossil Cryptogams explain the development of the exogenous medullary sheath, through the gradual separation of the vessels from the parenchymatous elements of the pith, until they constitute a distinct ring; the light thus thrown upon their origin further explaining why the ring of spiral vessels never recurs in the newer woody layers as they ought to do, if, as has been generally supposed, they belong to the inner part of the first formed ligneous zone, rather than to the pith which that zone incloses. It appears to me that this reasoning is justified by the facts upon which it is based. The principal weak point in it lies in the circumstance that in Exogens the spiral vessels supplied to the ribs of the leaves are derived from the medul-

* M. Brongniart, in his various writings, distinguishes the Lepidodendra from the Sigillariæ by the supposed absence from the former of the radiating woody cylinder; but his knowledge of the structure of the Lepidodendra was limited to the one specimen of *Lepidodendron* now become historically famous under the name of *L. Harcourtii*. The series of specimens which I have described demonstrates a gradual transition from the one type to the other, with which the French savant was necessarily unacquainted. He concluded that the vascular cylinder of *L. Harcourtii* solely represented the *inner* vascular cylinder of *Diploxylon*, which is certainly not the case. M. Brongniart had not seen the thin outer ring of small barred vessels occurring in plants of the type of *L. Harcourtii* as seen in my Plate XXV. fig. 14.

lary sheath, whilst in these fossil Cryptogams they are given off from the more external woody cylinder*; but this difference may be explained by the fact that in the former plants the spirals of the medullary sheath are altogether different from the non-spiral ones in the woody zones, whilst in the latter the two classes of vessels have the same structure, and differ only in size. Hence in the Cryptogams the one set may be substituted for the other, which could not be done in the ordinary Exogens.

My supposition respecting the relations subsisting between the inner vascular ring of *Lepidodendron* and the medullary sheath of Exogens receives fresh support from the structure of *Stigmaria*. In the latter plant, now well known to be a Sigillaroid root, we find no inner or medullary cylinder of vessels. The ligneous zone receives a wonderful development; it is furnished with an abundance of medullary rays, and gives off numerous vascular bundles which are supplied to the epidermal rootlets that here occupy the place of leaves. We have here a parallel state of things to that seen in the roots of Exogens, in which in like manner the medullary sheath is wanting. This curious coincidence has not escaped the observant eye of M. BRONGNIART, who calls attention to it in his memoir on *Sigillaria elegans*†.

My specimens throw no direct light upon the structure of the vascular and medullary axis of the true Sigillariæ as distinguished from the Favularian type; but the cortical portions of all the plants, including the true Sigillariæ, exhibit what is practically an identity of structure. In all we have a remarkably thick spongy bark, reminding us in many of its features of that found in the living Cycads. This consisted either of parenchyma, prosenchyma, or of both combined, enclosed externally in a bast-layer of elongated prosenchymatous tubes, which in turn is invested by a layer of cellular parenchyma supporting the bases of leaves, the latter invariably consisting of the same form of parenchyma as the epiderm. M. BRONGNIART's specimen of *Sigillaria* (*Favularia*) *elegans* exhibits a central axis, the structure of which is nearly identical with that of my Plate XXVIII. figs. 33, 34. This, in its turn, only differs from the more ordinary forms of *Diploxylon*, in the crenulated outline which separates the ligneous zone from the cylinder of medullary vessels, giving to the exterior of the latter a fluted aspect like that of a Calamite, but without the transverse nodal constrictions of the latter genus. The Diploxylons again, as I have already shown, shade off into the ordinary forms of *Lepidodendron*, and are undoubtedly Lepidodendroid plants which have lost the central portions of their medullary axes. Remove the cellular tissues from the centre of the plant which I have represented in figs. 8 & 9, and we have, at once, the closest resemblance to WITHAM's *Anabathra* and CORDA's *Diploxylon*, as well as to those now under consideration. That WITHAM's plant is identical, in type, with mine, is further indicated by his tab. 8. fig. 12, where he exhibits one of the large compound medullary rays shown in my Plate XXVII. fig. 23. The cellular tissues have not been preserved in the medullary rays of BRONGNIART's *Sigillaria elegans*; but tab. 4. fig. 2 of his memoir shows that his plant

* The reverse proves to be the case, hence this objection disappears. See note on page 237.

† *Loc. cit.* p. 433.

possessed similar ones to those which WITHAM and I have figured. Further, the description which M. BRONGNIART has given of the structure of the *outer* bark and epiderm of his plant, these being the only cortical elements remaining in his specimen, would apply with little or no alteration to several of my Lepidodendroid and Sigillarian types; so that whilst a really indisputable *Sigillaria*, like my Plate XXIX. fig. 39, but in which the woody axis is preserved *in situ*, is still an important desideratum, I have very little doubt that, when discovered, it will be found to correspond with one of the several varieties of *Diploxylon*. Most probably also my Plate XXV. fig. 8, representing one of the extreme of the two types figured by Mr. BINNEY under the name of *Sigillaria vascularis*, will also be found to belong to the same subtype of the same genus. Yet my indefatigable friend informs me that his cabinet contains specimens in which the most gradual transition can be traced from the plant just referred to to the *Lepidodendron selaginoides*, the oppositely divergent form of the same group; hence his inclusion of both under one common name.

Of the form recently described by Dr. DAWSON* I know nothing, having seen nothing like it amongst our Lancashire Coal-measures. He describes a coniferous type of glandular prosenchyma as occurring in the woody axis of his *Sigillaria*. I have not seen a single fibre of this kind in any of our Sigillarian or Lepidodendroid forms, neither have I met with any trace of a Sternbergian pith such as he describes in the same plant, which evidently belong to a different type from those of our English Coal-measures, assuming it to be what Dr. DAWSON supposes, viz. a true *Sigillaria*.

If, then, I am correct in thus bringing the Lepidodendra and Sigillariæ into such close affinity, there is an end of M. BRONGNIART'S theory, that the latter were Gymnospermous Exogens, because the Cryptogamic character of the former is disputed by no one; we must rather conclude, as I have done, that the entire series represents, along with the Calamites, an exogenous group of Cryptogams in which the woody zone separated a medullary from a cortical portion. The Cryptogamic type of structure remains in the universal, if not even exclusive, prevalence of barred vessels, a modification of that scalariform type so characteristic of living Cryptogams. The medulla in some cases fails to attain to the simple parenchymatous condition common amongst Exogens; nor does the bark, as already observed, exhibit the division into epiphlœum, mesophlœum, and endophlœum. But neither can these divisions be traced in the Cycads, with which, in some respects, the carboniferous stems exhibit remarkable affinities.

The semivascular bast-layer of the epiderm of these Lepidodendroid and Sigillaroid plants has played an important part in their preservation; it has arrested the decay which appears to have usually commenced in the inner bark, simultaneously perhaps with that of the cells of the medulla, though the latter not unfrequently remain after the former have disappeared. From the not unfrequent occurrence of the vascular woody cylinders deprived of bark, I suspect that they have not been so often involved

* "On the Structure and Affinities of *Sigillaria*, *Calamites*, and *Calamodendron*, by J. W. DAWSON, LL.D., F.R.S., &c., Principal of M'Gill University," Quarterly Journal of the Geological Society, London, May 1871.

in the decay that has overtaken the cellular structures as that they have become loosened from their attachments by that decay, and floated out when water reached them. Be this as it may, it is the bast-layer, with its investment of thick-walled epidermal cells, which has furnished, in nearly every case, the carbonaceous film that covers the stems of the Lepidodendroid plants so abundant in the shales and sandstones of the Coal-measures. The differences so obvious between the aspect of the outer surface of the thin film of coal and that of the subjacent shale are too well known to require further reference. When the carbonaceous matter is detached, the specimens are spoken of as being *decorticated*; and there may be no objection to the retention of a convenient term provided we distinctly understand the sense in which it is used. In all such instances the entire woody and inner cortical structures equally disappeared. The part which remained was, as I have already pointed out, the epidermal layer, with the semifibrous portion of the prosenchymatous one, which I have invariably found in every specimen that I have examined in which the structure is preserved. This bast-layer evidently gave to the bark the faculty of resisting the decay which so effectually cleared out all the more central tissues. It was this double layer which constituted the cylinder, the two sides of which were brought together and flattened by superimposed pressure when the stems were prostrated, and which constituted the hollow mould into which mud and sand were poured when they remained erect. We thus learn that very large trees were flattened into a thin layer, not because their stems were succulent, but because these hard woody and cellular cortical tissues broke up or were floated out of their epidermal sheath; whilst the latter, though strong and tough, was sufficiently flexible to yield to the superincumbent pressure, often without any material degree of disturbance of its integrity through fractures. Hence the fine flat masses of *Sigillaria* and *Lepidodendron* not unfrequently met with under the conditions which I have described.

It is a remarkable circumstance that whilst the woody zone is the part that has so frequently disappeared amongst the larger specimens of Lepidodendroid plants, and especially amongst the Sigillariæ, it is the part which is the most frequently preserved in the Stigmarian roots of the latter plant. I presume that this fact is to be explained by the different circumstances surrounding the two structures. The stems overthrown by storms were equally exposed to the decomposing influences of a warm humid atmosphere, whether they were prostrated on the ground or stood up as decapitated stumps. Such atmospheric influences would speedily destroy all but the tough superficial layers. The roots, on the other hand, imbedded deeply in wet mud, would be preserved from all atmospheric action; hence the beautiful preservation of their vascular tissues: these are often compressed and displaced, but rarely destroyed. The cellular bark, on the other hand, with the exception of the epidermal layer, and also the medullary cells, have yielded much more frequently to the decomposing influences that surrounded them even though protected by the soil.

What we know of the origin of the leaf-scars in living plants has left little room for hesitation respecting their nature in the fossils under consideration; but some of the

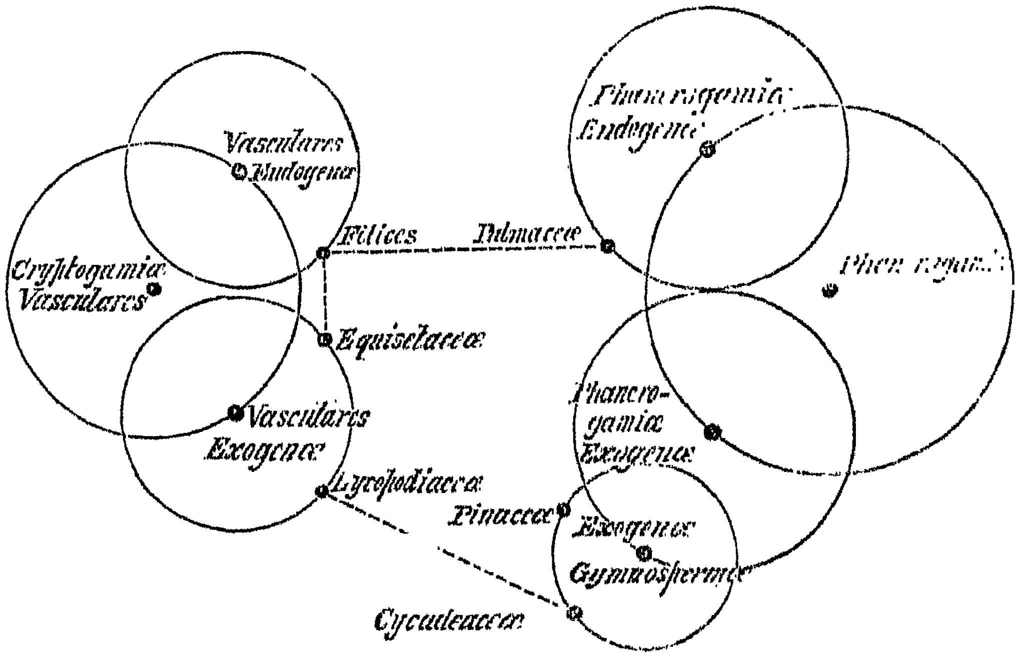
observations which I have recorded place the matter beyond doubt. Such examples as figs. 15, 17, 18, & 19, taken in connexion with figs. 5 & 6, make plain what are the portions of the stem which furnish the appearances so commonly found in fossil examples. The only question that is doubtful refers to the way in which the bases of the petioles of the fallen fronds have become detached. They evidently withered into membranous laminæ, as in some living Cycads and many tree-ferns; but whether they became detached bodily, leaving a well-defined cicatrix marking their base, as in ordinary deciduous trees, or whether the shrivelled stump of the petiole was worn down gradually by atmospheric decay, as in *Encephalartos caffre* and other allied Cycads, is not easy to say. I am inclined to conclude that the latter was the true process; but in either case a surface *was* reached, corresponding with the outer surface of the epiderm, at which a well-defined cicatrix of parenchymatous cells, of small size and with thickened walls, arrested further decomposition. Our knowledge of the relations of fruits to stems is too vague to enable us, as yet, to arrive at any definite conclusions respecting those of *Halonia*; but if the scars which I have referred to in *Ulodendron* and *Halonia* really supported cones, they were planted upon the subepidermal surface of the outer bark, and, like the leaves and rootlets, only received a vascular bundle to supply them with nutriment. What I mean is, that there appears to have been no deflection to these scars of any large portion of the vascular axis, which would have been the case had these curious organs given origin to branches.

It appears to me that, connecting the preceding observations with those made in my previous memoir on Calamites, we are called upon to make some change in the generally accepted views respecting the classification and nomenclature of the living vascular Cryptogams.

To apply the term *Acrogens* to plants which grew up into magnificent forest trees, the structure and growth of whose stems was essentially exogenous, whilst those stems exhibited so many of the internal features of exogenous organization, is surely an error. Until the close affinities of the Lepidodrendra with the Sigillariæ was established by actual observation, I do not wonder that M. BRONGNIART insisted upon his belief that the latter were Gymnospermous Exogens. I do not see how this Gymnospermous theory can be entertained any longer; but to make the facts upon which it was based accord with our systems we must alter the latter.

In the discussion which followed the reading of my memoir on Calamites before the Royal Society in January 1871, Dr. CARPENTER threw out a suggestion which accords with my own conclusions on the question. One great distinction between the Exogens and Endogens is to be found in the fact that, when a formation of vessels is made in the woody zone of the former type, the clusters of vessels are left uninclosed, and consequently capable of receiving any amount of addition to their number without interference with the continuity of the series. On the other hand, the opposite is the case with the Endogens. Here each cluster of vessels is incased in a dense cylinder of woody prosenchyma, which latter always interferes to interrupt all continuous additions to the former tissues. If we turn to the Cryptogams, especially as illuminated by the study of

the fossil forms, we find that the stems of the Calamites, the approximate representatives of the Equisetaceæ, and those of the Lepidodendra with their extreme Sigillarian modifications, are of the exogenous type, whilst those of ferns are, in the points referred to, as obviously endogenous. The respective affinities of these plants, so far as the stems are concerned, may be represented by some such diagram as the following.



It will be observed that in this memoir I have paid but little attention to generic distinctions and none to specific ones, because I am satisfied that we are not yet in a position to define either the one or the other. My object has been to ascertain, as far as I could, what are the principal types of structure, and what the ranges of their variation; but, on the latter point especially, very much remains to be done which can only be accomplished by the cooperation of multiplied observers, and especially of such as are investigating distinct localities where new varieties may be expected to obtain. By such observations alone can our mutual errors and oversights be corrected. Where examples of plants in which structure is preserved are rare, we are in danger of drawing general conclusions from individual varieties which happen to be sharply defined: hence it is most important that independent observers should not be deterred from again going over the ground by an idea that it is preoccupied or that the work is done. The present contribution, however, carefully executed as far as it goes, is but that of a pioneer in a very wide and almost unexplored field.

It only remains for me to acknowledge the assistance which I have received either in the loan of sections or, what has been of even greater value to me, of specimens for dissection. The gentlemen to whom I have been thus indebted are W. Boyd Dawkins, Esq., F.R.S., of Manchester, Mr. J. Butterworth, of Shaw, and Mr. Whittaker and Mr. Nield, of Oldham. The scientific liberality of my two last-named auxiliaries demands special notice. They have not only given me the freest access to their cabinets, but have allowed me to cut into fragments some of the choicest specimens which they contained, when the interests of scientific truth seemed to demand the sacrifice. Such a spirit is too rare not to merit the thanks of all investigators whenever it is met with.

Description of the Plates.

The same letters are employed throughout to represent, as far as possible, what appear to be homologous parts, in accordance with the following plan:—

a. Medullary axis.
b. Cells of medullary axis.
c. Vessels of medullary axis.
d. Ligneous zone.
e. Vessels of ligneous zone.
f. Medullary rays.
g. Innermost part of the bark.
h. Middle parenchymatous part of the bark.
i. Outer or prosenchymatous part of the bark.
k. Tubular portion of *i.*
l. Bases of leaves or petioles, detached or coalesced into an epidermal layer.
m. Bundles of vessels going to the leaves.
n. Bundles of vessels going to the rootlets.
o. Rootlets.
p. Indentations of epiderm in which rootlets are planted.
r. Scars or cicatrices from which cones are supposed to have fallen.

Where not otherwise specifically mentioned, the specimens represented are in the author's cabinet. The collectors from whom some of the fossils were received are named, but the sections, in these examples, are also in the author's cabinet.

Plate

XXIV. fig. 1. *Lepidodendron selaginoides*, a young branch, transverse section, magnified 6 diameters. Mr. BUTTERWORTH's cabinet.

,, fig. 2. *Lepidodendron selaginoides*, longitudinal section of fig. 1, magnified 4 diameters. Mr. BUTTERWORTH's cabinet.

,, fig. 3. *Lepidodendron selaginoides*, part of medullary centre of fig. 1, magnified 200 diameters.

,, fig. 4. *Lepidodendron selaginoides*, part of medullary centre of fig. 2, magnified 70 diameters.

,, fig. 5. *Lepidodendron selaginoides*, tangential section of outer bark immediately below the epiderm, magnified 7 diameters. Mr. BUTTERWORTH's cabinet.

,, fig. 6. *Lepidodendron selaginoides*, tangential section of outer layer of epiderm at the base of the petioles, magnified 7 diameters. Mr. BUTTERWORTH's cabinet.

XXV. fig. 7. *Lepidodendron selaginoides*, subepidermal surface of outer bark, nat. size.

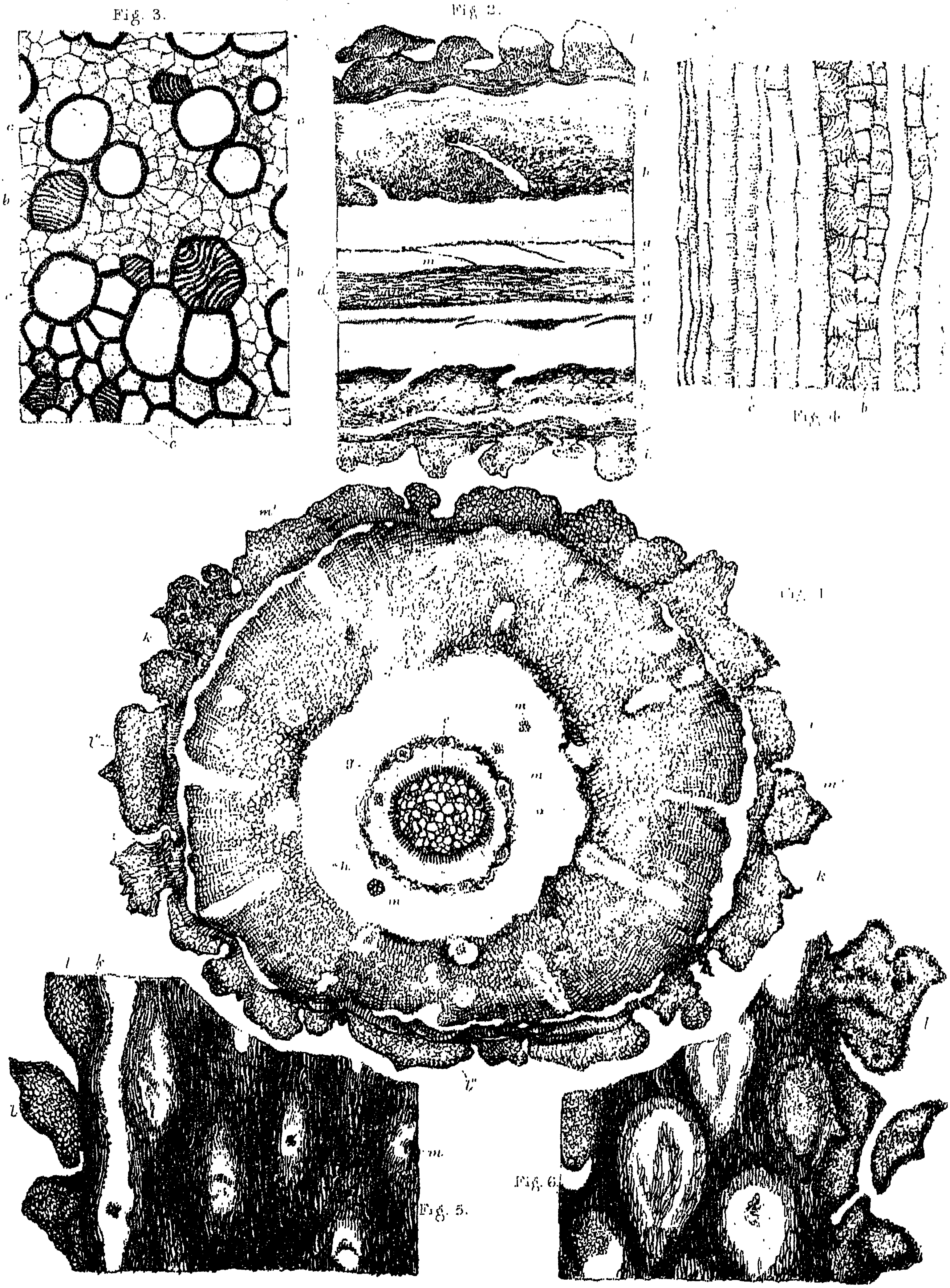
,, fig. 8. Transverse section of central axis, woody zone, and part of the inner bark of one form of the *Sigillaria vascularis* of Mr. BINNEY's memoir, magnified 10 diameters. Mr. BUTTERWORTH's cabinet.

,, fig. 9. Longitudinal section of fig. 8, magnified 10 diameters. Mr. BUTTERWORTH's cabinet.

fig. 10. Tangential section of the woody zone of the same type as fig. 8, showing the medullary rays.

fig. 11. Prosenchyma of the bark of fig. 10, magnified 400 diameters.

fig. 12. *Lepidodendron*, transverse section, nat. size. Mr. W. B. DAWKINS's cabinet.



W.C. Williamson del. E. M. W lith.

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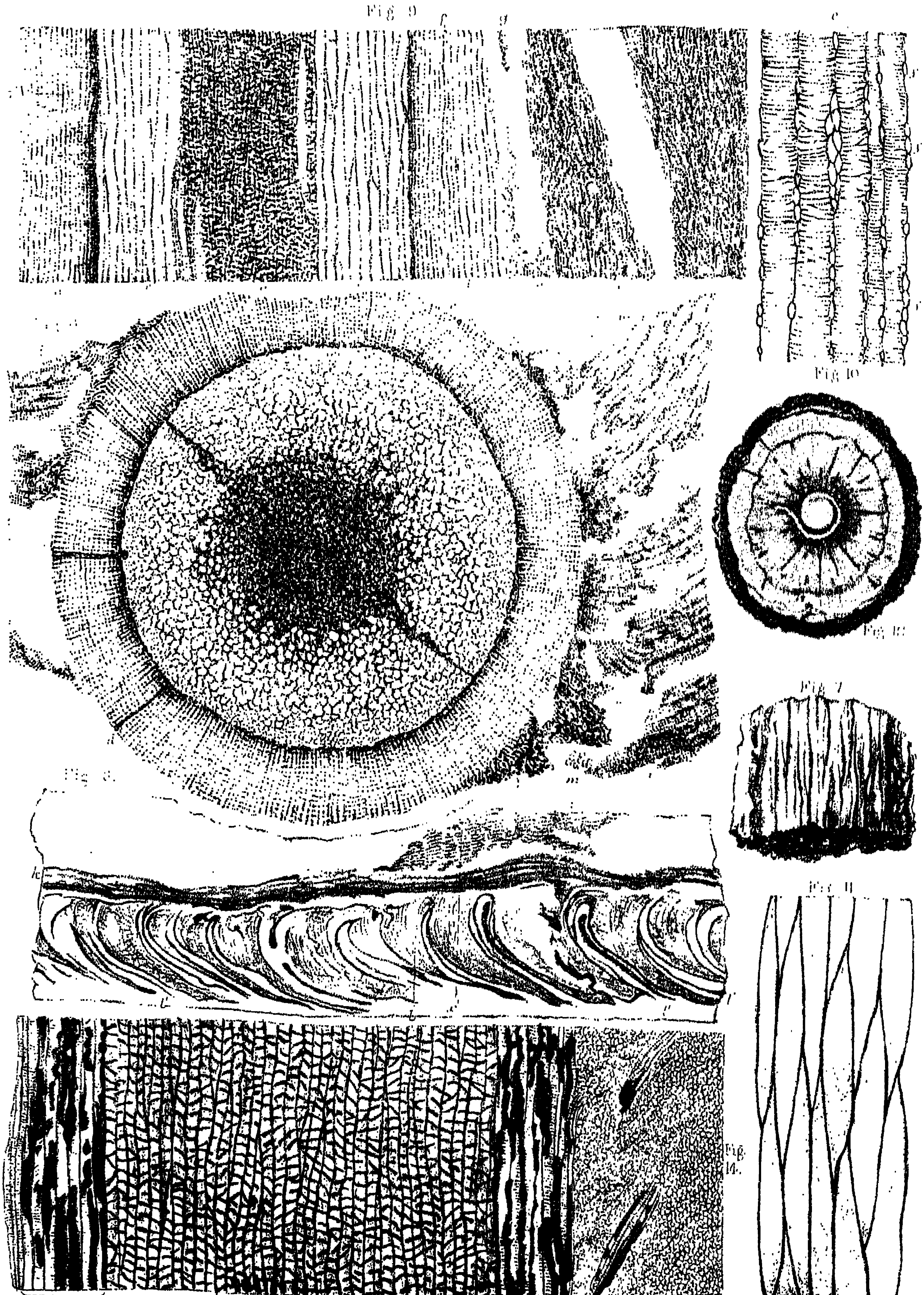

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Fig. 17.

Fig. 13.

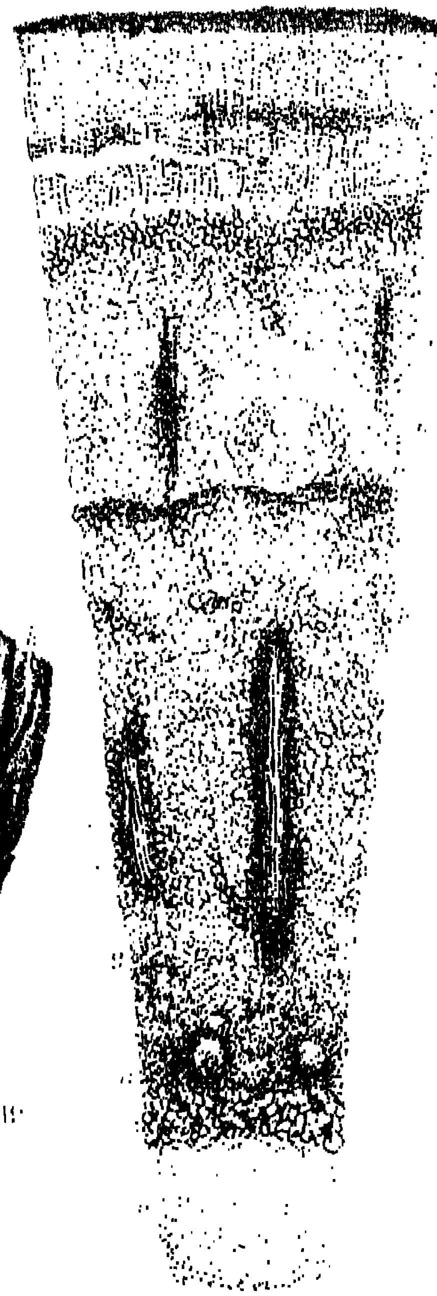


Fig. 18.

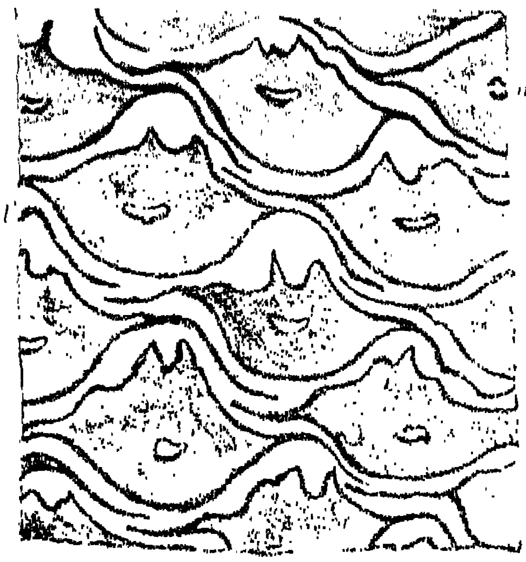


Fig. 19.

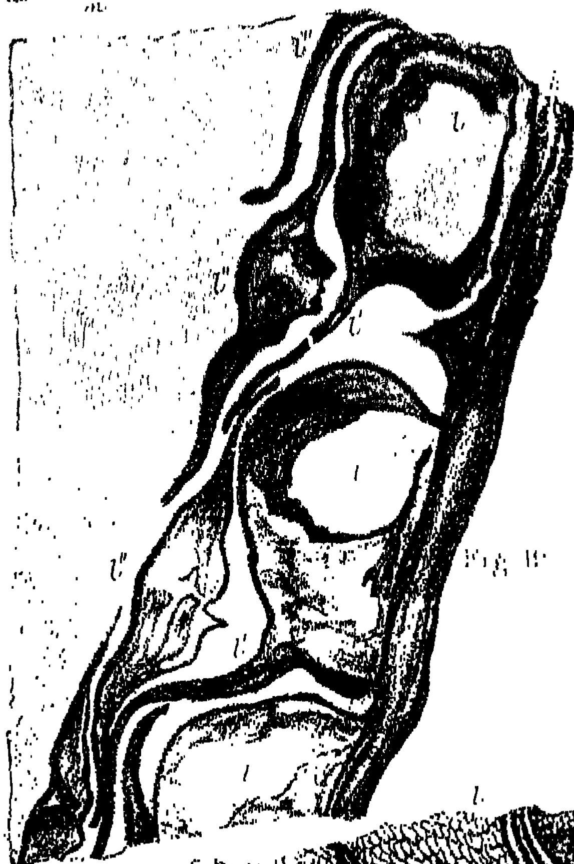


Fig. 20.

Fig. 21.

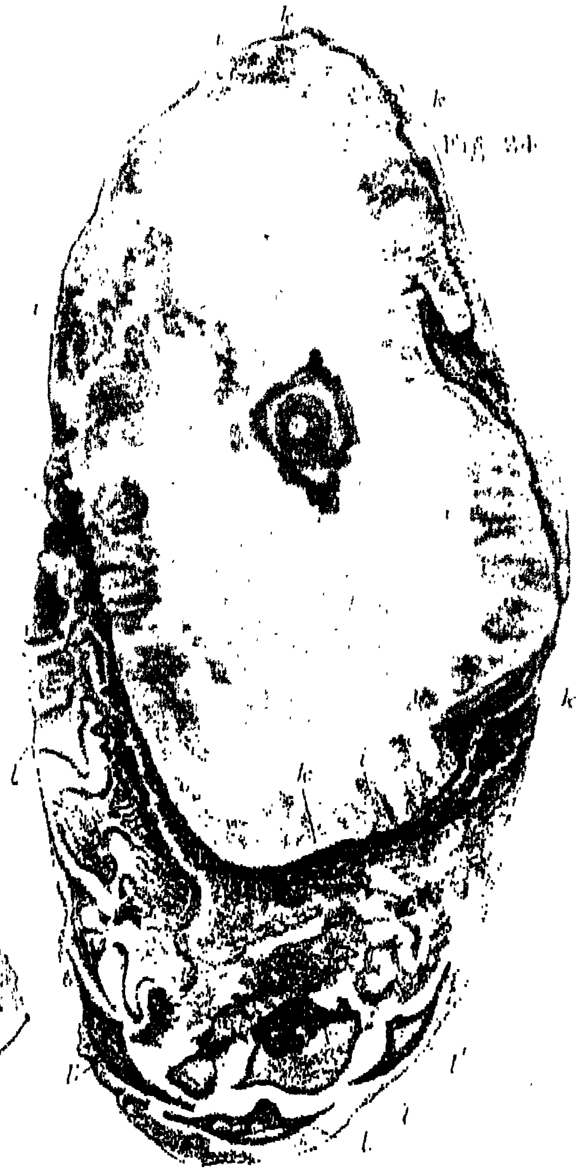


Fig. 15.

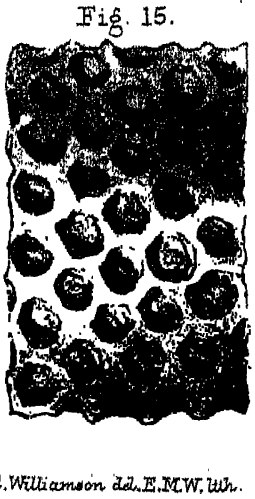
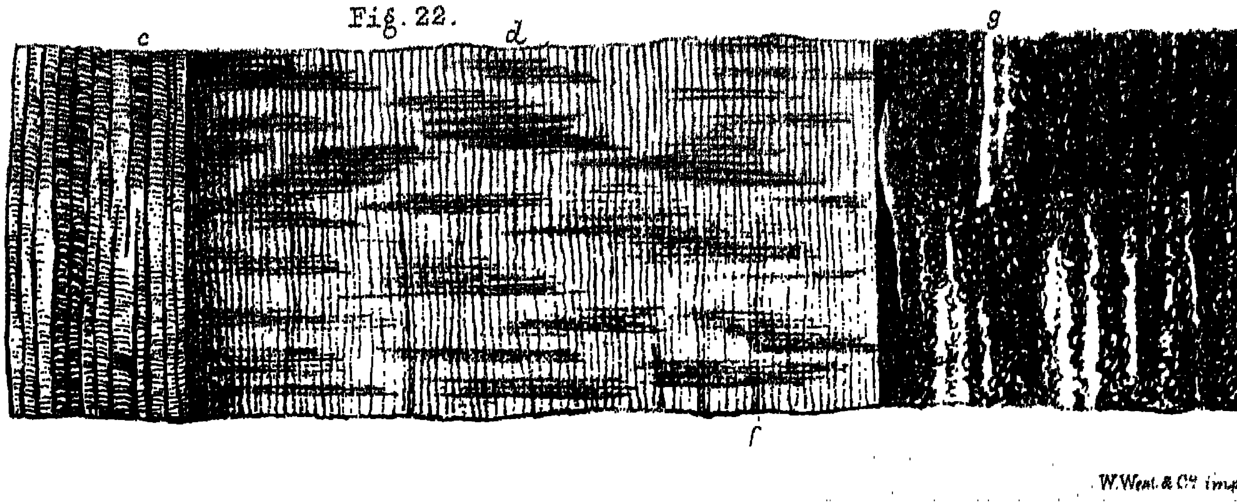


Fig. 22.



W.C. Williamson del. E.M.W. lith.

W. West & Co. imp.

Fig. 25

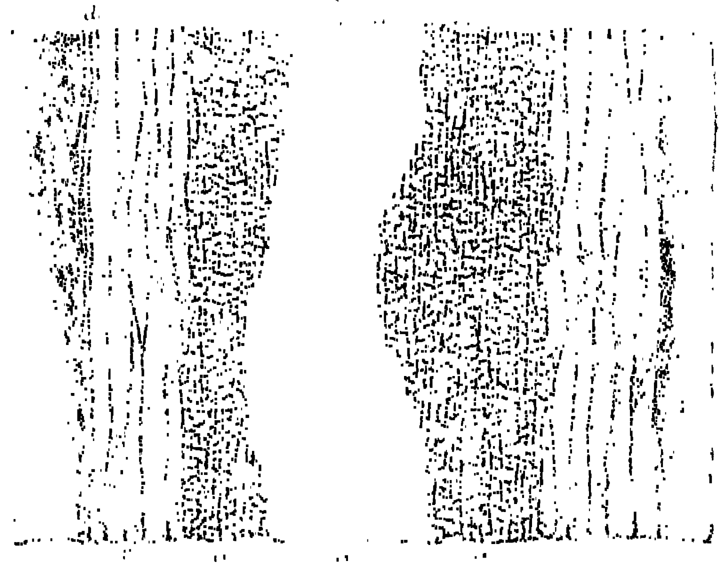


Fig. 26

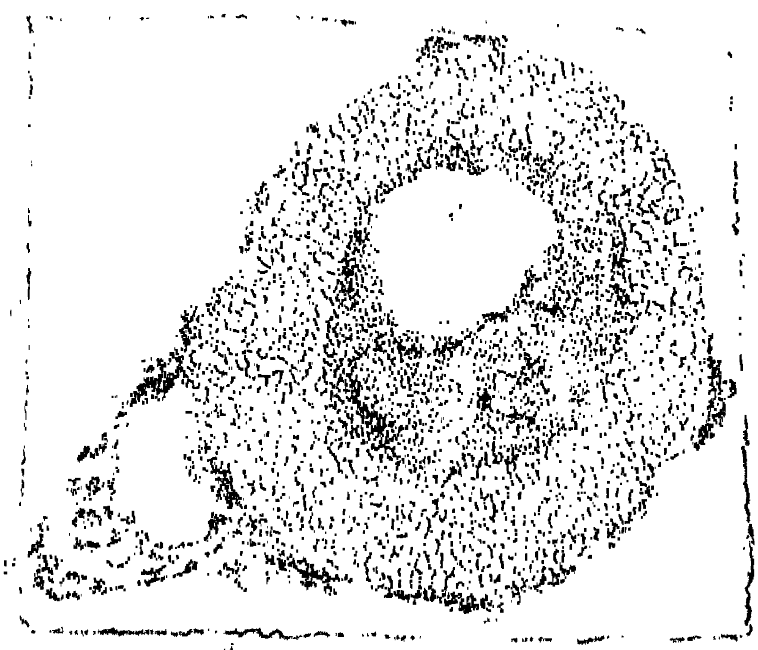


Fig. 23 a.

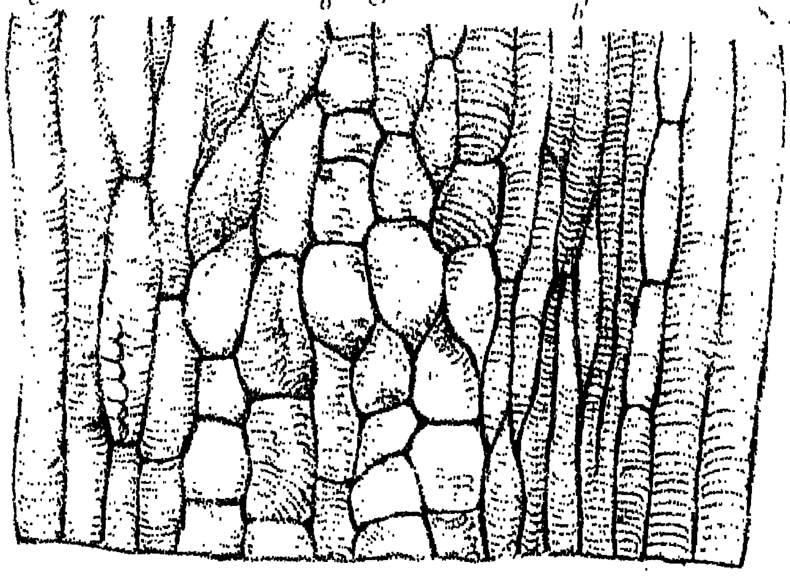


Fig. 29.

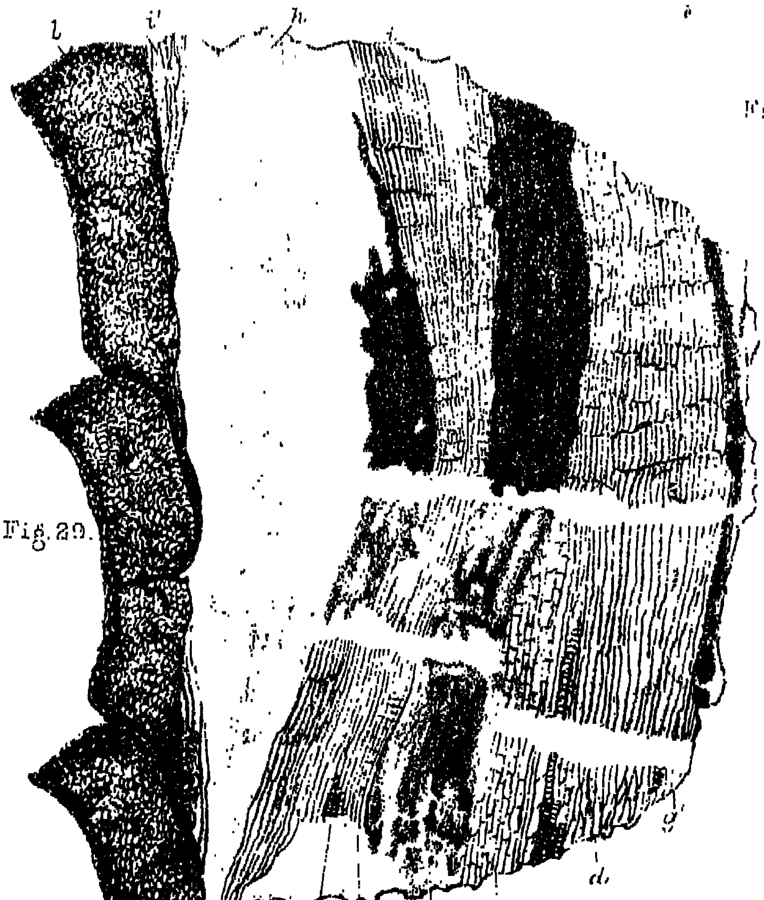
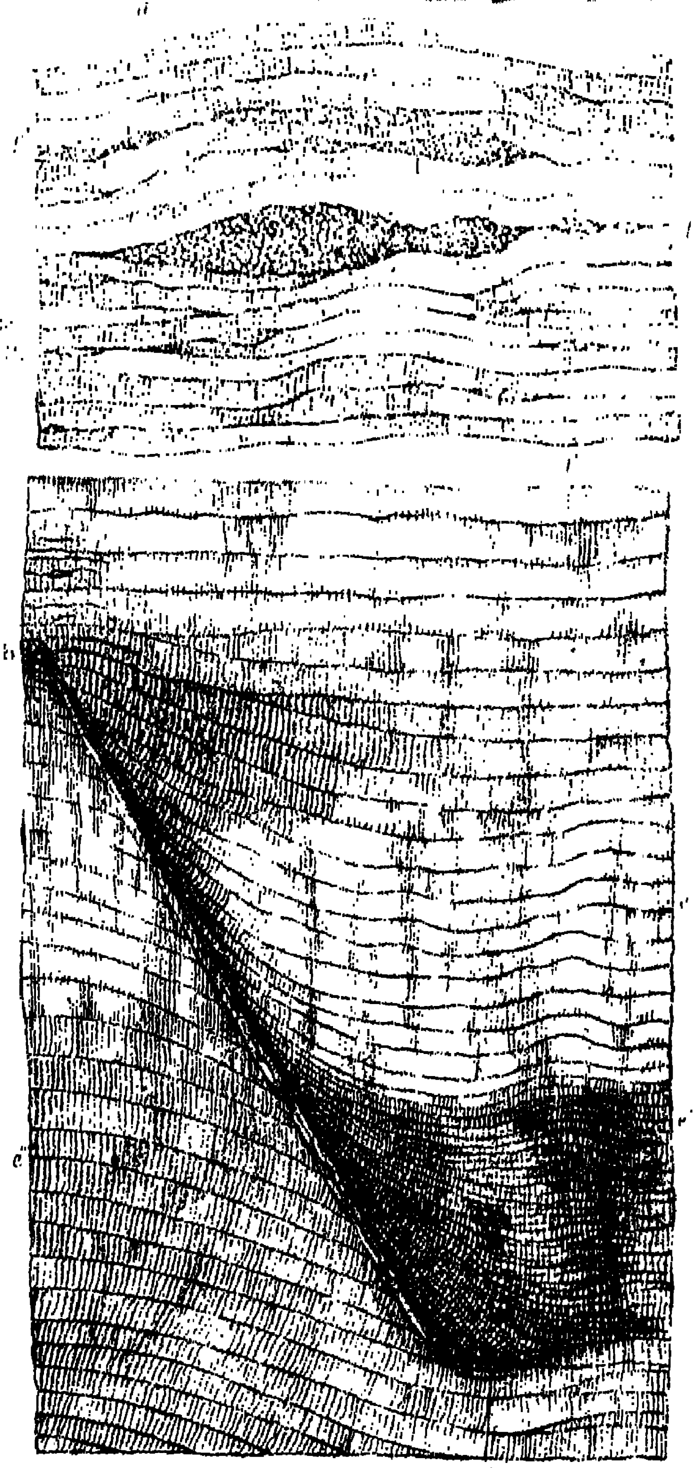
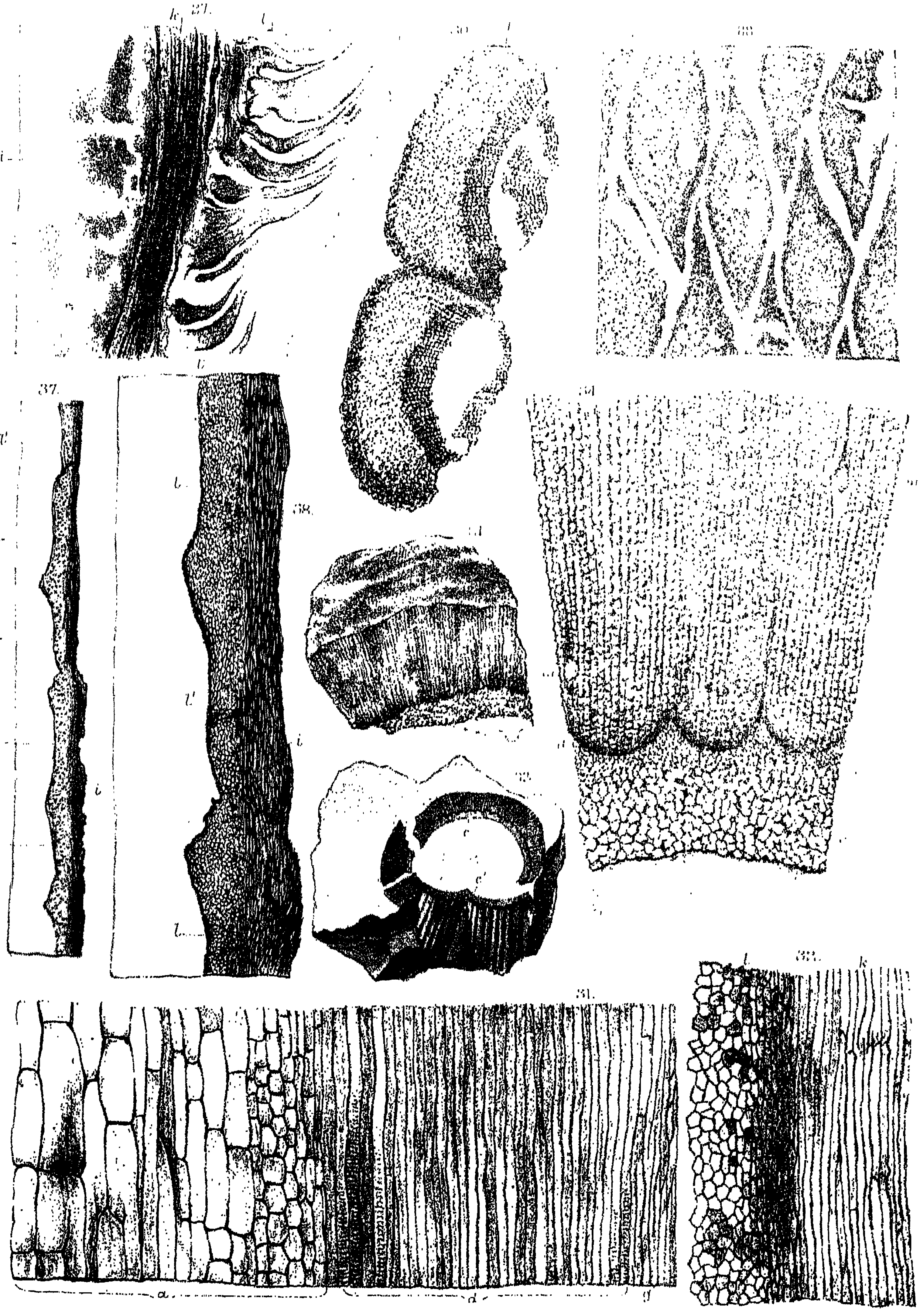


Fig. 23 b



W.C. Williamson del. E.M.W. lith.

W. West & Co imp.



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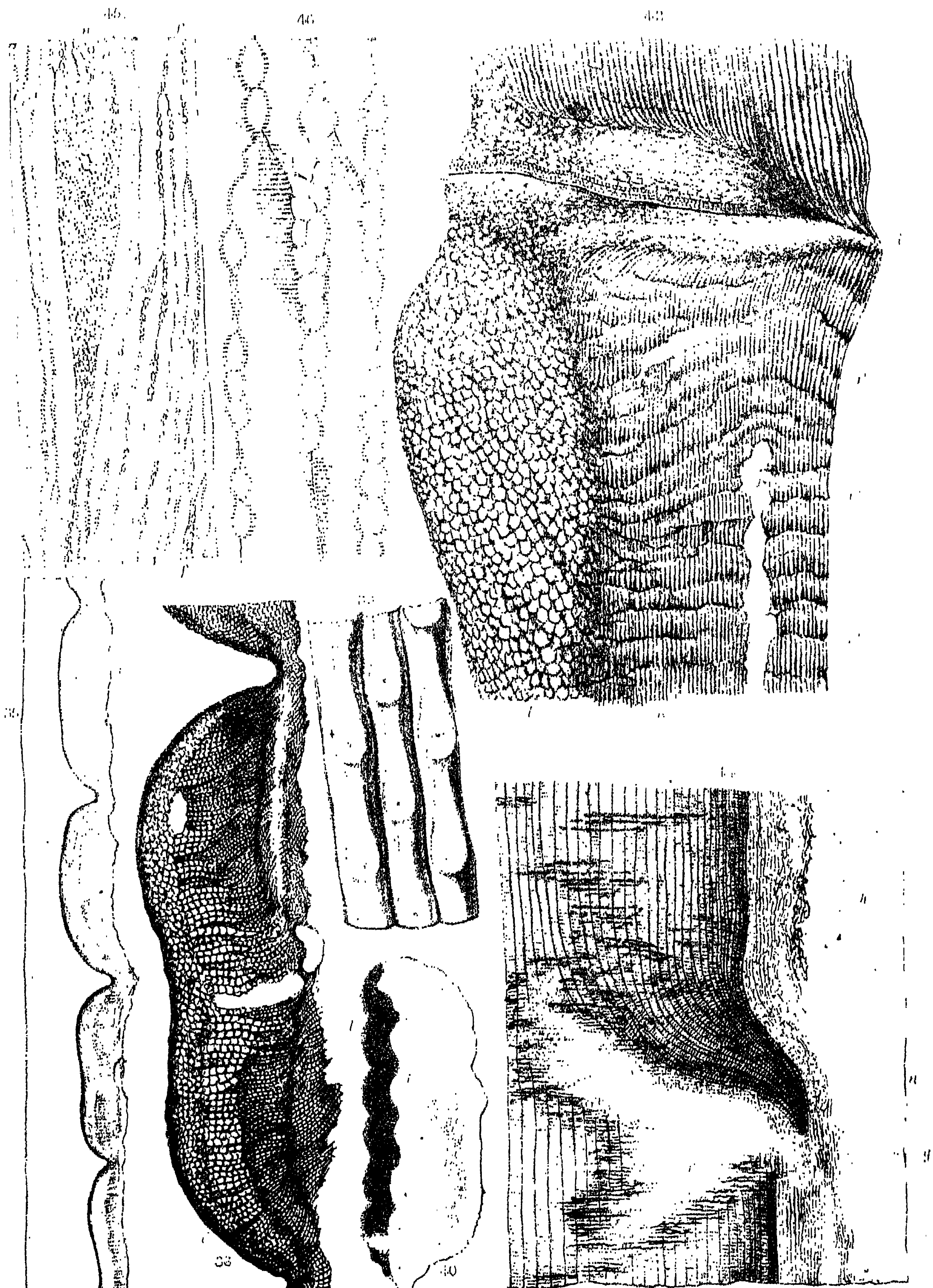

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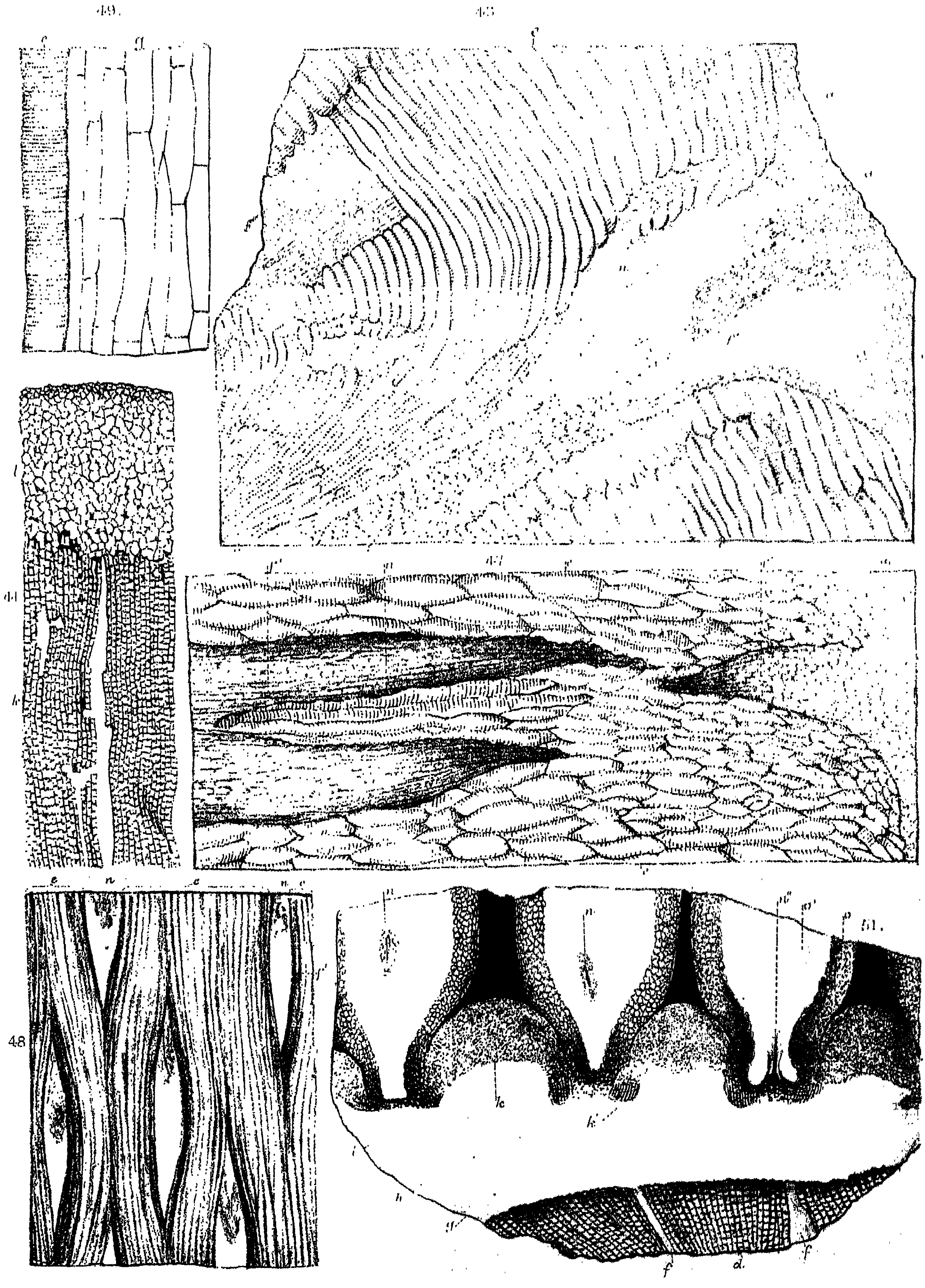

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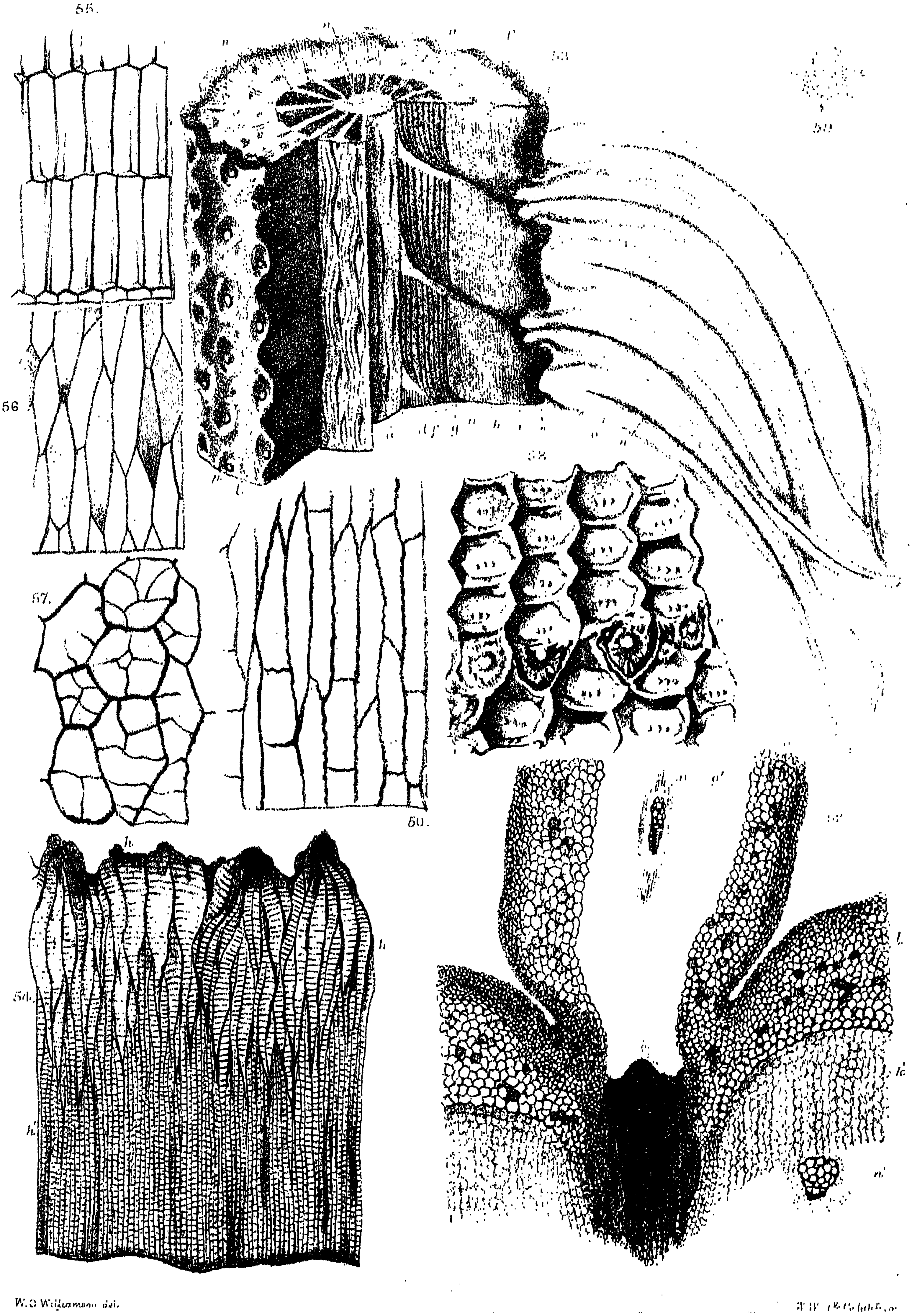
55.
56
57.

Plate

XXVIII. fig. 34. *Diploxylon*, segment of a transverse section of fig. 33, magnified 15 diameters.

XXIX. fig. 35. *Sigillaria*, transverse section of the epidermal layer of the bark, magnified 4 diameters.

„ fig. 36. *Sigillaria*, one rib of fig. 35, enlarged 13 diameters.

XXVIII. fig. 37. *Sigillaria*, radial section made along the centre of one of the raised longitudinal ribs of fig. 35, magnified 4 diameters.

„ fig. 38. *Sigillaria*, portion of fig. 37, enlarged 12 diameters.

XXIX. fig. 39. *Sigillaria*, part of the surface of the specimen. Mr. NIELD.

„ fig. 40. *Sigillaria*, transverse section of the epidermal layer of fig. 39, natural size.

XXX. fig. 41. *Sigillaria*, a segment of fig. 40, enlarged 15 diameters.

XXIX. fig. 42. *Sigillaria*, vertical section through the centre of a part of one rib of fig. 39, showing the vascular bundle going to the base of the petiole, magnified 15 diameters.

XXX. fig. 43. Stigmarian root, radial section of the innermost part of the woody zone, with a medullary ray and vascular bundle going off towards a rootlet, magnified 13 diameters. Mr. WHITTAKER.

XXIX. fig. 44. Stigmarian root, radial section like fig. 43, but of the outermost part of the ligneous zone, with medullary ray and vascular bundle, magnified 10 diameters.

„ fig. 45. Stigmarian root, tangential section of part of the ligneous zone, with one primary and numerous secondary medullary rays, magnified 13 diameters.

„ fig. 46. Stigmarian root, part of fig. 45, with secondary medullary rays, magnified 50 diameters.

XXX. fig. 47. Stigmarian root, transverse section of the innermost part of the woody zone, with a medullary ray and vascular bundle going to a rootlet, magnified 15 diameters.

„ fig. 48. Stigmarian root, outer surface of the ligneous zone, with the peripheral extremities of the primary medullary rays and vascular bundles of the rootlets, magnified 4 diameters. Mr. WHITTAKER'S cabinet.

„ fig. 49. Stigmarian root, radial section of the innermost bark, magnified 120 diameters.

XXXI. fig. 50. Stigmarian root, tangential section of the middle bark, magnified 100 diameters.

XXX. fig. 51. Stigmarian root, bases of three rootlets, with the epidermal layer upon which they are implanted, magnified 3 diameters.

XXXI. fig. 52. Stigmarian root, base of one rootlet, magnified 6 diameters. Mr. NIELD.

„ fig. 53. Stigmarian root, diagram representing a restoration of the entire root, with the surfaces of the pith, wood, and bark successively displayed in the

Plate

XXVI. fig. 13. *Lepidodendron*, segment of fig. 12, magnified 8 diameters.

XXV. fig. 14. *Lepidodendron*, vertical section of the centre of the same plant as fig. 12. Mr. W. B. DAWKINS.

XXVI. fig. 15. *Lepidodendron*, subepidermal surface of the bark of the same species as fig. 12. Mr. BUTTERWORTH's cabinet.

XXV. fig. 16. *Lepidodendron*, vertical section of epidermal layer and petioles of leaves, $2\frac{1}{2}$ diameters. Mr. W. B. DAWKINS's cabinet.

XXVI. fig. 17. *Lepidodendron*, tangential section through outermost layer of epidermis, magnified 3 diameters. Mr. DAWKINS.

" fig. 18. *Lepidodendron*, tangential section of the same specimen as fig. 17, but nearer the extremities of the intersected leaves, magnified 3 diameters.

" fig. 19. *Lepidodendron*, oblique transverse section of fig. 17, magnified 3 diameters.

" fig. 20. *Lepidodendron*, vertical section of another specimen similar to figs. 16–19, magnified 4 diameters. Mr. WHITTAKER.

XXVIII. fig. 21. *Diploxylon*, transverse section, nat. size. Mr. BUTTERWORTH.

XXVI. fig. 22. *Diploxylon*, vertical section of fig. 21, magnified 5 diameters.

XXVII. fig. 23. *Diploxylon*, tangential section of some of the vessels of the ligneous zone and medullary rays of fig. 21.

" fig. 23 *a*. Radial section of fig. 21 at the inner surface of the ligneous zone.

" fig. 23 *b*. Radial section through the ligneous zone of *Diploxylon stigmarioideum*.

XXVI. fig. 24. *Ulodendron*, transverse section, magnified 2 diameters. Mr. NIELD.

XXVII. fig. 25. *Ulodendron*, longitudinal section of the central axis of fig. 24, magnified 12 diameters.

" fig. 26. *Ulodendron*, central axis of fig. 24, magnified 12 diameters.

XXVIII. fig. 27. *Ulodendron*, longitudinal section of outer bark, epidermis, and petioles of fig. 25, magnified 3 diameters.

" fig. 28. *Ulodendron*, tangential section of bases of petioles close to the epiderm, magnified 6 diameters.

XXVII. fig. 29. *Favularia*, longitudinal section, magnified 6 diameters. Mr. WHITTAKER.

XXVIII. fig. 30. *Favularia*, transverse section of the bases of two petioles of fig. 29, magnified 6 diameters.

" fig. 31. *Favularia*, portion of fig. 29, showing the medulla, woody zone, and a trace of the inner bark, magnified 30 diameters.

" fig. 32. *Favularia*, portion of the epidermis of fig. 29, showing the outer parenchyma and the bast-layer, enlarged.

" fig. 33. *Diploxylon*, aspect of the specimen before it was cut up into sections, nat. size. Mr. NIELD.

Plate

centre and to the left of the diagram, and with a section of the wood and bark, the latter with the rootlets *in situ*, on the right. The latter section is supposed to have passed directly through the centres of the bases of *two* of the rootlets, and tangentially through the remaining *three*.

XXXI. fig. 54. Transverse section of a fragment of bark, apparently of *Diploxylon*, magnified 16 diameters. Mr. BUTTERWORTH.

„ fig. 55. Radial section of the prosenchymatous portion of a similar specimen to fig. 54, magnified 65 diameters.

„ fig. 56. Tangential section of fig. 55, magnified 65 diameters.

„ fig. 57. Tangential section of the large cells (*h*) of fig. 54, magnified 60 diameters.

„ fig. 58. Cast of the external surface of a *Favularia*, with cicatrices of cones, enlarged 2 diameters. Mr. NIELD's cabinet.

„ fig. 59. Central axis of a small Lepidodendroid cone, enlarged 2 diameters.

Received September 3, 1871.

SUPPLEMENTARY OBSERVATIONS.

Since reading the preceding memoir I have been seeking further information on some portions of the subject which are as yet very obscure, especially in connexion with the forms represented by the *Diploxylon cycadeoideum* of CORDA. In his 'Flora der Vorwelt' he gives both the generic and specific characters of this plant. The essential features of the former are that the plants belonging to the genus have an *inner* cylinder surrounding the medulla composed of large scalariform vessels arranged without definite order. This is invested by a second cylinder, also consisting of scalariform vessels, but of smaller size, arranged in radiating fasciculi, and "*radiis vasorum ligni interni percursum.*" In his specific description of *D. cycadeoideum* he affirms "Radii medullaris nulli" (*loc. cit.* pp. 5, 6). In his tab. xi. fig. 1 he represents a radial longitudinal section in which three sharply defined vascular bundles, unaccompanied by any other tissue, proceed upwards and outwards across a field of vertical, barred vessels, which are disposed with rigid straightness and perfect parallelism. I think I shall not be venturing too far if I doubt the perfect accuracy of this figure. But what is of chief importance at present is the fact that he believes these vascular bundles *to spring from his inner or medullary rings of vessels*, and not from any part of the outer or ligneous zone, and that he discovers *no traces of cellular medullary rays* in his specimen.

M. BRONGNIART, as we have seen, found a very similar general arrangement in his *Sigillaria elegans*, only in this plant the inner or medullary vascular cylinder was interrupted, at intervals, instead of being a continuous ring. He also found a profusion of what he unhesitatingly affirms to be medullary rays; but the tissues which composed them being destroyed, he cannot speak with confidence as to their histological character. Besides these he found traces of larger openings in the woody cylinder; and he correctly surmises that these were passages through which the large foliar vascular bundles, seen

penetrating the bark, had emerged from the ligneous zone. He expresses himself very doubtfully as to the source of these bundles; but observing what he deems to be indications of them in the transverse section of the *outer* ligneous cylinder, *close to the inner one*, he thinks they may possibly have originated in the latter.

The third writer whose observations bear upon the question is Professor KING, whose able and lucid paper* contains an admirable account of all that was known of these plants at the time when his memoir was published. In it he discusses the structure of the *Anabathra* of WITHAM, having had in his possession a number of that distinguished observer's original specimens. In this plant, as I have already mentioned in the preceding memoir, we have the inner medullary cylinder and the outer ligneous zone of vessels arranged as in BRONGNIART'S *Sigillaria* and in *Diploxylon*; only, as in the latter plant, it constituted a continuous instead of an interrupted ring. Professor KING calls attention to the large lenticular openings, seen in the tangential sections of the woody zone of *Anabathra*, figured and described by WITHAM as medullary rays. He says respecting them, "Mr. WITHAM described these openings as containing the medullary rays, which is not the case, because what has probably been mistaken for cellular tissue is, in reality, a bundle of small vessels, similar to those which occupy the outer part of the medullary sheath. Although the longitudinal sections do not exhibit any of these bundles springing from the vascular cylinder, their proximity in some transverse sections, together with the fact just stated, leave no room to doubt their having constituted the leaf-cords of the plant." This writer further adds, "from these passages being in part vacant, it may reasonably be supposed that the cords were accompanied in their course with a portion of cellular tissue"†.

It thus appears that all three of the above writers inclined to the idea that the foliar vascular bundles arise from the vessels of the vascular medullary sheaths of the plants which they severally describe. In the previous pages I pointed out that whilst in some Diploxylons the line of demarcation between the medullary sheath and the ligneous zone was a crenulated one, in others it appeared to be straight. Having recently prepared and examined a large number of additional sections, I find that even in some of the examples in which I thought the line was a straight one I can detect a series of *small* crenulations. This I have especially found to be the case with the specimen represented in figs. 20–23. In this plant the crenulations resemble those seen in fig. 31, though much more minute. The latter figure shows at c' what appear to be angular projections of the medullary sheath penetrating between the large convex, inner extremities of the fasciculi of the woody zone. I now find that in the plant in question these projecting angles are not wholly occupied by medullary *vessels*, but contain a remarkable arrangement of *barred cells*. Fig. 23 *a* represents a small portion of a radial longitudinal section of this part of the plant, in which *c* represents the outermost vessels of the medullary sheath, *e* the *inner* vessels of the woody zone, and the cells *b* the structure

* "Contributions towards establishing the generic characters of the fossil plants of the genus *Sigillaria*, by WILLIAM KING, Esq.," Edinburgh New Philosophical Journal, Nos. 71 *et seq.*

† *Loc. cit.* p. 124.

referred to. It will be observed that some of these cells are nearly cubical in shape, others more elongated; some have square ends, others oblique ones; but it is important to notice that towards the exterior of this cellular mass (b') the cells exhibit a strong tendency to become prosenchymatous. All these cells, where mineralization has not altered their structure, are more or less regularly barred. Where the convex inner extremity of each fasciculus of the woody zone encroaches upon the medullary sheath, this cellular layer almost disappears, though not altogether so. The large lenticular radii to which allusion has been made *take their rise in this cellular tissue.* My specimens show that the longer axis of each cell becomes suddenly deflected in the horizontal direction. That such is the case is shown, not only by their general aspect, but by the reversal of the direction of their transverse bars, which are now vertical, and not horizontal as before. Many of these deflected cells are perfectly muriform, but others are more or less prosenchymatous. In the immediate neighbourhood of the cellular tract there is a considerable disturbance of the parallelism of the small contiguous barred vessels, so that the origin of such of the latter as contribute to the formation of the foliar bundle is not easily traced; but, however originated, some of them accompany the deflected cells to constitute that bundle. In no case do any of the inner and larger vessels of the medullary sheath take any part in the formation of these bundles; and my present impression is that all those which do so should rather be regarded as belonging to the innermost part of the woody zone than to the exterior of the medullary cylinder*. Whichever is the fact, I am convinced that these vessels are the exact equivalents of those furnishing the foliar bundles in the true Lepidodendra. These bundles were needed, in the very earliest stage of the growth of the young shoot, to sustain the developing leaves; and though at this stage of its development the woody zone was obviously represented in a very feeble manner, it nevertheless fulfilled its functions in contributing its quota to the foliar nutrition. But there remains to be explained the supposed absence of true medullary rays mentioned by CORDA as characterizing his *Diploxylon*, but which were observed by BRONGNIART in his *Sigillaria elegans*. None of these writers were aware of the existence of barred or scalariform *cells* in the medullæ of these plants. Consequently when CORDA found barred tissues running horizontally, not only in the *large* lenticular spaces separating the ligneous fasciculi, but also in the *smaller* ones separating individual laminæ, he concluded that *all* these were necessarily bundles of barred *vessels*, and in consequence denied the existence of medullary rays. Since, however, all the medullary cells of many of these Lepidodendroid plants (see figs. 1 & 3) are barred, it follows that some of those in other portions of the ligneous zone would, in all probability, be the same; and such proves to be the case. In the example which I am now describing it is difficult in some places to say which are sections of fusiform cells, and which of parts of contorted vessels; but in a large number of specimens

* Later researches amongst the Burntisland plants have enabled me to clear up this very obscure point, and to determine that the vessels in question do belong *to the outermost surface* of the medullary cylinder. See Proceedings of Royal Society, vol. xx. p. 199.—May 7th, 1872.

there is no difficulty in establishing the conjoint existence of the two tissues; hence I venture to affirm that, in *Diploxylon cycadeoideum*, we have two distinct forms of medullary rays: 1st, the larger lenticular ones, which are primarily composed of barred cells, but through which the vascular bundles escape to the surface of the woody zone; and 2nd, of smaller ones, in which similarly barred cells are chiefly, though not invariably, arranged in tangential sections in single vertical rows, often not containing more than two or three cells in each vertical series, but which constitute true medullary rays.

In the preceding memoir I have designated the large lenticular spaces *primary* medullary rays, to distinguish them from the smaller or *secondary* ones. Those botanists who, like Mr. CARRUTHERS, wholly repudiate the existence of any parallelism between these fossil Cryptogams and the more highly developed Phanerogamic Exogens, consistently deny that any of these cellular horizontal communications between the interior and exterior of the woody zone are representatives of or entitled to be called medullary rays; but BRONGNIART, than whom it would be difficult to quote a higher authority, so designated both the larger and the smaller ones in *Stigmaria ficoides*, as well as illustrated them by what are found in *Zamia integrifolia* and other Cycads ("Observations sur le *Sigillaria elegans*"), and I am convinced that he is right in so doing. It is as impossible to separate these Cryptogamic forms of medullary rays from those of the Cycadeæ on the one hand, as it is to disjoin the latter from those of the higher Coniferа on the other. Professor KING quotes the late Dr. LINDLEY'S opinion that no vascular bundles ever issued through medullary rays. This may be true in the case of Phanerogamic Exogens, but it does not follow that it must be equally true of these Cryptogamic modifications of the exogenous type of woody zone. One thing is clear, viz. that the large lenticular spaces (my *primary* medullary rays) are but modifications of the smaller or secondary ones, enlarged to serve a special teleological purpose; i. e. *the transmission of vascular bundles to the leaves and rootlets*. At their upper and lower extremities these large elliptical cellular rays are undistinguishable from and merge in the smaller ones. However large and thick in their central portion, they diminish in size upwards and downwards, both in the Diploxylons and in *Stigmaria*, until they contract into laminæ consisting of a single thin vertical layer of cells. Such teleological modifications are universal amongst animals; and I fail to see why we should refuse to recognize their existence amongst plants. At all events until some better reasons for doing so are furnished by those who differ from me than they have hitherto advanced, I shall continue to follow the example of M. BRONGNIART, and employ the terms adopted in the preceding pages.

Having thus obtained additional light respecting the Diploxylons, I again turned to the more highly organized of the stems described by Mr. BINNEY under the name of *Sigillaria vascularis*, and which I have already represented in Plate XXV. figs. 8–11. I made a fresh series of carefully prepared dissections, and succeeded in demonstrating the existence in this plant of a series of primary and secondary medullary rays, the former containing large foliar bundles, precisely identical with those of *Diploxylon cycadeoideum*. I have not succeeded in discovering in the former plant the cellular layer

intervening between the medullary vascular cylinder and the woody zone of the latter one. The large primary medullary rays are composed of barred cells, which are sometimes mural, but more frequently prosenchymatous; through the upper part of each of these large rays there proceeds a bundle of true barred vessels. I have not succeeded in tracing one of these bundles to its medullary extremity, consequently I cannot yet affirm how it originates; but I have seen sufficient to confirm what I have already stated in the body of the memoir, that we need only remove the central cellular medulla of the plant in question to convert it into a true *Diploxylon*; the identity of the two, so far as structural type is concerned, is as close as it can be, even in its minuter details. Such being my conviction, I propose to designate the plant represented in figs. 8–11 *Diploxylon vasculare*, and to apply CORDA's name of *D. cycadeoideum* to figs. 21–23. The plant represented by figs. 33, 34, distinguished by its large medullary axis and by the deeply fluted aspect of the interior surface of its ligneous zone, I propose to designate *Diploxylon cylindricum*, whilst a fourth form, exhibiting some different features yet to be noticed, I would term *D. stigmarioideum*. So far as the general structure of the stem is concerned the last-named plant does not differ from the other Diploxylons. The cellular medulla has disappeared, but there remains the medullary ring of barred vessels, surrounded by the exogenous ligneous zone. The primary and secondary medullary rays also appear; but neither of them occurs so abundantly as in the other species. Moreover, in the radial vertical sections, the vascular bundles occupying the primary rays exhibit a different aspect to those of the other species described, and approach nearer to what exists in *Stigmaria ficoides*. This is represented in fig. 23 *b*. The vascular bundle (*m*) appears to be derived from the body of the ligneous zone and not from its medullary surface. It is composed of smaller vessels than those seen at *e*; but we find that at *e'* these vessels diminish in size and approach in magnitude those of the bundle *m*; not only so, but whilst the upper extremities of the small vessels of *m* exhibit the perpendicular arrangement indicating that they belong to the part of the woody zone in which they occur, the lower extremities of the large vessels (*e*) are deflected in the direction of those of the foliar bundle, which is never the case with the corresponding ones of the other forms of Diploxylons. The lower margin of the foliar bundle is cut off in this section by an oblique, sharply defined line; this indicates that the large vessels at *e''* have been sharply deflected to the right and left of the bundle to allow the latter to pass between them. All these appearances correspond so closely with what we find in *Stigmaria*, that for a long time this plant seriously perplexed me; but it appears to be a true *Diploxylon*, since it has the vascular medullary cylinder of that genus as well defined as in any other species. This cylinder is never found in *Stigmaria ficoides*. It has been more especially in connexion with this species of *Diploxylon*, though not exclusively, that I have found the peculiar bark represented in figs. 54–57. It is possible that this plant may, like *Stigmaria*, prove to be the uppermost part of a root of some of the other forms, though I have never yet found it associated with any rootlets; or it may be a fragment from the base where stem and roots united.

Amongst the numerous other interesting plants for which I am indebted to G. GRIEVE, Esq., of Burntisland, in Fifeshire, is a well-marked *Diploxylon* closely allied to *D. cycadeoideum*. Like the rest of Mr. GRIEVE's specimens, it is from the deposit of lower carboniferous age which occurs imbedded amongst trappean rocks at Pettycur Bay. This specimen is an instructive one, since, though abundantly furnished with primary and secondary medullary rays, or rather with the spaces which they occupied, all the *cellular* tissues have disappeared from both, whilst the *vascular* foliar bundles are well preserved. We are thus enabled to distinguish the respective areas occupied by the two tissues in a manner that I have not succeeded in doing so distinctly in the other specimens described. Each bundle is cylindrical, occupying the centre of the lenticular section of the ray when cut at right angles to its direction, and consisting of very small barred vessels. Above and below the vessels are open spaces, but which were originally occupied by the cellular tissues of the ray, the forms of the cells being strongly impressed upon the indented walls of the contiguous longitudinal vessels of the ligneous zone. I have not discovered in this plant the cellular layer intervening between the medullary vascular cylinder and the woody zone; in this respect it appears to approach nearer to the *D. vasculare* than to the other forms. The vascular medullary cylinder or sheath is strongly marked; but all the medullary cellular tissues have disappeared. I pointed out some time ago* that some of these Lepidodendra exhibited a feature not previously noticed; viz. the vessels were not only barred transversely, but, in addition, the transverse bars of lignine were connected by a delicate series of threads of the same material, running parallel with the longer axis of the vessel. I find this feature in all the Diploxylons; but in the Burntisland specimen it is so faint that it can only be discovered under the microscope by a careful adjustment of the light. The coarser transverse bars are also much more irregular in size, number, and direction than is usual amongst the Diploxylons of the Upper Coal-measures.

The *Diploxylon* of CORDA is so obviously identical, generically, with the *Anabathra* of WITHAM, that the latter name ought to be adopted in preference to the former one. But ere long, in all probability, both these names will have to be abandoned, since there appears to be little doubt that they represent the woody axes of some of the common Lepidodendroid plants of the Coal-measures; and as soon as the identification of these internal axes with their correlate external forms is indisputably accomplished, the yet older names of the latter must become the adopted ones. Under these circumstances it is scarcely desirable to disturb a widely accepted nomenclature, since any day may furnish the required connecting link.

The general conclusion towards which all these additional observations point is the same as that of the preceding memoir, which they strengthen and confirm, viz. that all these varied plants are constructed upon a common type, and belong to one Lycopodiaceous family.

* Monthly Microscopical Journal, August 1, 1869, pl. xx. fig. 10.

Owens College, Manchester, August 30, 1871.

XI. *On the Fossil Mammals of Australia.*—Part VII. *Genus* Phascolomys: *species exceeding the existing ones in size. By Professor* Owen, *F.R.S. &c.*

Received March 25,—Read April 18, 1872.

In a former communication* I applied the cranial, mandibular, and dental characters of the existing species of Wombat to the determination of the fossil species resembling them in size; in the present are given the results of an easier task, viz. the determination of extinct Wombats of markedly superior size to any now living; and I shall describe the fossils as the species they represent progressively predominate in bulk.

§ 1. *Phascolomys medius*, Ow.—This species is represented by a lower jaw, fractured at both ends, presented by Sir Charles Nicholson, Bart., to the Geological Society of London; also by the fore part of the upper jaw of two individuals and by the right ramus, fractured at both ends, of the lower jaw, obtained by Edward S. Hill, Esq., from freshwater deposits exposed in the bed of a tributary of the Condamine River, at Eton Vale, Queensland: the latter were submitted to me in 1865, and have been liberally presented, with other Queensland fossils, to the British Museum by Sir Daniel Cooper, Bart. All these fossils are in the usual heavy, petrified, rolled, and more or less mutilated condition of such remains from the above formation and locality.

The first to be described (Plate XXXII. figs. 2–7) consists of so much of the premaxillary ($_{22}$) and maxillary ($_{21}$) bones as includes the sockets of the incisors (i) and of the first three molars (d_3, d_4, m_1, fig. 2), with part of that of the fourth, m_2. The incisors are broken off at the level of their alveolar outlets (fig. 6, i); the first and second molars, left side, show their natural grinding-surface; part of that of the following tooth is broken; the rest of the molars are more or less mutilated or wanting.

The superiority in size of the present extinct species to the two largest of the existing Wombats will be seen by comparing the above-cited figures, especially fig. 2, Plate XXXII., with the corresponding parts of the skull of *Phascolomys latifrons* (ib. fig. 1) and of *Phascolomys platyrhinus* (Plate XXXIII. fig. 1); it needs not to introduce the smaller Tasmanian Wombat into the comparison.

The following admeasurements give the degree, or value, of the character from the size of teeth and extent of diastema of the species above cited:—

	P. medius.		*P. platyrhinus.*		*P. latifrons.*	
	inches.	lines.	inch.	lines.	inch.	lines.
Antero-posterior extent of grinding-surfaces of d_3, d_4, m_1	1	6	1	2	1	0
Antero-posterior extent of diastema (l to i) . .			1	7	1	9

* Philosophical Transactions, 1872, p. 173.

In the relative length of the interval between the socket of the incisor (Plate XXXII. fig. 2, *i*) and that of the anterior molar (d_3), the present fossil resembles the latifront species (ib. fig. 1, *l*, $_{22'}$, *i*). The same relationship is shown in the form of the intermolar part of the bony palate, which is less contracted anteriorly in the fossil than in the bare-nosed Wombats (*Phascolomys platyrhinus*, Plate XXXIII. fig. 1*). The entire bony palate is more concave transversely in the hairy-nosed Wombat than in the other recent kinds; and this character is more strongly marked in the fossil, especially in the depth of the diastemal palatal tract into which open the "incisive" or premaxillo-maxillary palatal foramina (Plate XXXII. fig. 2, *a*, *a*). This deeply arched form of the bony roof of the mouth will be again noted in larger extinct species of Wombat.

The present appears to have been one half larger than the largest individuals of *Phascolomys platyrhinus*. In a specimen of this existing species, the length of the diastema equals three fifteenths of that of the entire skull, which is 7 inches 5 lines (Plate XXXIII. fig. 1, $_{21'}$, $_{22'}$). If the diastema bore the same proportion in *Phascolomys medius*, the length of its skull may be set down at 1 foot 6 inches.

The first molar (Plate XXXII. fig. 2, d_3), with the usual curvature, concave outward, and with the exposed part inclined obliquely backward, has a grinding-surface, or transverse section, of an oval form, with the small end forwards. The long diameter is 5 lines, and is in the direction of the molar series; the greatest transverse diameter is 4 lines. The enamel does not extend from the inner surface so far outward upon either the front or back parts of the tooth as in the recent Wombats; it shows no trace of the antero-internal fold which is feebly marked in *Phascolomys latifrons*, and strongly marked in *Phascolomys platyrhinus* and *Phasc. vombatus*. The coat of cement covering the outer side of the tooth is continued in a thinner layer over part of the enamel, and where absent has been probably accidentally removed from that partial deposit of the hardest dental tissue.

The second molar (ib. d_4) is divided by the usual deep inner groove and shallow outer one into two lobes, the hinder one being broader both transversely and from before backward. The antero-posterior extent of the grinding-surface is $7\frac{1}{2}$ lines, the transverse extent of the front lobe is 4 lines, of the hind lobe $4\frac{1}{2}$ lines; the inner end of this lobe is less obtusely rounded than that of the front lobe. From the unequal depth of the outer and inner alveolar walls, only a small part (about a line) of the unenamelled outer part of the tooth projects from the socket, while an extent of four lines of the inner enamelled part of the tooth projects beyond the lower inner alveolar wall (Plate XXXII. fig. 7, d_4). The enamel-coat is thinner at the bottom of the inner inflection or groove, and terminates near the rounded external angles of the tooth: portions of the thin cement covering the enamel are preserved.

The third molar (ib. fig. 2, m_1) resembles d_4 in size and shape; the anterior lobe does not extend so far inward as the contiguous lobe of the antecedent molar. The portion of the anterior lobe preserved of the fourth molar (m_2) shows the same relative

* See also Trans. Zool. Soc. vol. ii. plate lxxi. fig. 6 (*Phascolomys vombatus*).

position to the hind lobe of m_1. The enamel in all the molars is longitudinally striate, the striæ being feebly marked and subrugose.

Completing the upper molar series according to the analogy of *Phascolomys latifrons*, its antero-posterior extent would be about 2 inches 8 lines; and this is the extent shown in a photograph (Plate XXXV. fig. 7), nat. size, of a portion of the upper jaw of *Phascolomys medius*, with the entire molar series of the right side, from the breccia-cave of Wellington Valley, New South Wales, in the Australian Museum, Sydney, for which I am indebted to the Trustees of that Museum and their able Curator, Mr. KREFFT.

The margin of the diastemal part of the upper jaw (Plate XXXII. fig. 2, *l*) is sharp to near the incisive outlets (*i*), where it broadens and becomes obtuse. The cross section of the incisor (ib. fig. 6) is a transverse oval, 6 lines in long diameter, $4\frac{1}{2}$ lines in short diameter; the small end of the oval is obtuse and turned outward. The enamel bends from above a very short way down upon the inner side or large end of the oval; it arches down over the small end. The enamelled surface of the tooth is more convex than the hind or lower cement-clad surface; but this is more convex, or less flattened, than in *Phascolomys latifrons*. The long and short diameters of the transverse section of the incisor in the other two living species are in opposite directions to those in the present fossil and the Latifront Wombat.

In *Phascolomys medius* the malar process of the maxillary (Plate XXXII. fig. 3, $_{21^a}$) rises thirteen lines above the alveolus of the third molar: the intervening wall of the maxillary is moderately concave vertically; in the smaller living Wombats it is convex; but in the character of height of origin of the process we again have an evidence of affinity to the latifront species. The photograph (Plate XXXV. fig. 7) shows a close correspondence with the fossil in this character.

The prezygomatic ridge (Plate XXXII. fig. 3, *m*) is low and broad, but in course and length resembles that in *Phascolomys latifrons*; in *Phasc. platyrhinus* this ridge is shorter, relatively thicker, and more prominent. Anterior to the ridge and the socket of d_3 the maxillary part of the skull of *Phasc. medius* contracts transversely, seemingly more suddenly than in existing Wombats, to form the diastemal part of the upper jaw. The maxillo-premaxillary suture runs vertically, with a sinuous and strongly denticulate course, about 5 lines in advance of the socket of d_3. The front walls of the incisive sockets (Plate XXXII. figs. 3, 4, & 5, $_{22}$, $_{22}$) are relatively higher or deeper than in *Phascolomys latifrons*, in which they are relatively higher than in the bare-nosed Wombats. The contour of this part of the premaxillary is rather concave in the fossil.

The photograph above referred to (Plate XXXV. fig. 7) of the cave fossil shows the same depth and shape of the bony palate, and the same somewhat abrupt contraction of the diastemal part of the maxillary, as in the fossil (Plate XXXII. fig. 2) from Eton Vale.

These evidences of specific distinction, superadded to the marked superiority of size of *Phascolomys medius*, are acceptable; although the degree of constancy of size and shape of teeth in the three species of living Wombats would have justified an inference, from

the teeth alone of the present fossil, that a still larger Wombat than the platyrhine continental species had formerly existed in both Queensland and New South Wales.

As so much, however, depends on ascertained constancy of characters in the comparative work preliminary to determination of extinct species, I believe it will be acceptable to palæontologists to have a description and figures of a fossil of *Phascolomys medius* somewhat larger than the subject of Plate XXXII. figs. 2–7.

The fore-and-aft extent of the first three molars in fig. 2, Plate XXXIII., is 1 inch 11 lines; in fig. 2, Plate XXXII., the same dimension yields 1 inch 8 lines. The closer agreement, as to size, in all other parts of the two fossils leads me to regard the above dental difference as coming within the limits of age- or sex-variation. The present fossil has been more crushed than the former; the socket of d_3 may have been pressed forward a little way from that of d_4, and so have contributed somewhat to the above difference. It is singular how the post mortem or posthumous violence has operated so as to detach almost the same parts and proportion of the fore part of the skull from the remainder in both representatives of *Phascolomys medius*. Some transversely acting force has nipped in the maxillaries in advance of the sockets of d_3, breaking the diastemal from the alveolar part of the left maxillary and crushing it inwards; this, in the present fossil, has somewhat approximated the right and left anterior molars (d_3, d_4), and has converted the concavity of the palate at the hind part of the diastema into an angular cleft. But the fore part expands and conforms in character with that in the last-described fossil. The length of the diastema and the characters of its borders are the same. The differences mentioned are obviously accidental. Rather more of the anterior pier of the zygomatic arch is preserved on the left side of the present fossil (Plate XXXIII. fig. 3, $_{21*}$).

The first molar (d_3) and the incisors have the same shape as in Plate XXXII. Nearly the whole of the implanted part of the left incisor (i) is exposed in the subject of fig. 3, Plate XXXIII. The incisors slightly converge as they curve downward and forward to the outlets of their long sockets. The enamel shows the same longitudinal rugous striation as in the other fossil. In both the median ridge is shown along so much of the floor of the nasal passages as is exposed (ib. fig. 4, n). In fig. 6 is given an inside view of so much as is preserved of the molars of the left side, upper jaw, corresponding with that from the preceding fossil given at fig. 7, Plate XXXII.

With the two foregoing fossils I received from Queensland, through the same liberal and enlightened contributors of materials for the history of Australian marsupial fossils, the portion of mandible, with the entire molar series, figured in Plate XXXIV. figs. 1 & 2.

This fossil, from the size of the teeth and of the jaw supporting them, I refer to the same species as the upper jaw (Plates XXXII. & XXXIII.). It includes an extent of 5 inches of the right ramus, wanting both extremities, but with a symphysial portion of the left ramus (Plate XXXIV. fig. 2, v, i) adherent by matrix, though slightly displaced, showing that the joint (s) had not been obliterated.

The general curve of the lower contour resembles that of the mandible of *Phascolomys*

latifrons (Philosophical Transactions, 1872, Plate XXII. fig. 3). The anterior part of the origin of the coronoid (Plate XXXIV. fig. 1, *q*) bears the same relation to the penultimate molar, and is more advanced than in *Phascolomys platyrhinus*. The ectalveolar groove (ib. fig. 3, *u*) between this process and the last two alveoli is relatively narrower than in any of the living species. The fore part of the ectocrotaphyte depression (*f'*), bounded below by the prominent outstanding ridge (*h'*, *h*, fig. 1), is less deep than in the bare-nosed Wombats, and is more gradually excavated, as in the hairy-nosed species.

The ramus maintains its depth (1 inch 10 lines) to the socket of the first molar (Plate XXXIV. *d* 3, figs. 1 & 2). The hind part of the symphysis (ib. fig. 3, *s*) is on the vertical parallel of the hind part of the second molar (*d* 4), being rather more advanced than in *Phascolomys latifrons* (Philosophical Transactions, 1872, Plate XXI. fig. 3, *s*), and much more so than in *Phasc. platyrhinus* (ib. fig. 2, *s*) or *Phasc. vombatus* (ib. fig. 1, *s*). The upper surface of the symphysis (Plate XXXIV. fig. 3, *l*) repeats the character of the opposed palatal part of the upper jaw (Plate XXXII. & XXXIII. *w*, *w'*) in its degree of transverse concavity; and this, at the diastemal tract, is bounded by lateral ridges, sharper than those above; they indicate a slightly curved course as they advance, concave outward, so far as they extend in the fossil. These characters of the upper surface of the symphysis are most nearly repeated by *Phascolomys Krefftii* (Philosophical Transactions, 1872, Plate XX. fig. 2, *l*, *s*) amongst the smaller Wombats; but in that extinct species the symphysis extends back as far as it does in *Phasc. platyrhinus* or *Phasc. vombatus* (Philosophical Transactions, 1872, Plate XIX. figs. 1 & 2). In *Phasc. latifrons* the symphysis is shorter, more concave and more definitely bounded above than in the bare-nosed Wombats, but is not so much so as in *Phascolomys Krefftii*. The lower contour of the symphysis in *Phascolomys medius* rises at a less open angle with the axis of the ramus than in *Phasc. latifrons*, and still less so than in the bare-nosed species. The lower surface shows the pair of vascular outlets, of small size, 15 lines in advance of the hind border. The anterior outlet of the dental canal (Plate XXXIV. fig. 1, *v*) is relatively rather nearer the socket of *d* 3 than in the smaller fossil and recent Wombats. The vertical convexity of the outer wall of the ramus and comparative flatness of the postsymphysial inner wall are according to the generic type, and relate to the direction of convexity of the long, bent, deeply implanted, ever-growing molars.

The first molar (*d* 3, ib. figs. 1, 2, 3) has the usual generic small size and simple form, representing, as it were, like its homotype above, one half of the succeeding molars. The grinding-surface resembles that of the upper jaw in being suboval, with the long axis lengthwise. In this it differs from *Phascolomys latifrons*, *Phasc. Mitchelli*, and *Phasc. Krefftii*, in which that surface is subquadrate, and it resembles, rather, *Phascolomys platyrhinus*; but the larger end of the oval is at the fore part of the tooth in *Phasc. medius*, not at the hind part, as is usually seen in *Phasc. platyrhinus*. The fore part of *d* 3 in *Phasc. medius* shows a feeble longitudinal groove, as in *Phasc. latifrons*. The enamel, as usual, coats the outer and fore part of the tooth, but is not extended so far from the fore part upon the inner side as in *Phasc. latifrons*. There

seems to be a slight interruption in the course of the enamel at the middle of the fore part of the tooth, which I have noticed in some of the smaller Wombats. The enamel was coated by cement in the fossil.

The succeeding molars slightly decrease in breadth of grinding-surface from the third (m_1), the decrease being most marked in the hind lobe of the last molar. This character is more marked in *Phascolomys latifrons* than in *Phasc. platyrhinus*. The longitudinal extent of the series of five teeth in *Phascolomys medius* is 2 inches 6 lines, as against 2 inches 1 line in *Phasc. platyrhinus*, and 1 inch 8 lines in *Phasc. latifrons*.

The lower incisors of *Phascolomys medius* resemble in relative size those in *Phascolomys latifrons*, in which they are smaller than in the bare-nosed Wombats; but the shape of the transverse section in *Phasc. medius* is different (Plate XXXIV. fig. 4, *i*); it gives a full ellipse, $4\frac{1}{2}$ by $3\frac{1}{2}$ lines, with the long axis almost vertical, but obliquely inclined from above downward and rather inward. The enamel is thin, and limited to the lower half of the long procumbent tooth. They are smaller, especially narrower transversely, than the upper pair, and in this respect resemble the lower incisors of the hairy-nosed, not the bare-nosed, Wombats.

From the proportions which the extent of the molar series bears to the length of the entire mandible in existing Wombats, I estimate that the lower jaw in the present extinct species must have been between 6 and 7 inches in length.

§ 2. *Phascolomys magnus*, Ow.—This species is founded on two portions of the upper jaw, one containing the entire molar series of both sides (Plate XXXV. figs. 1–4), the other retaining the second, third, and fourth molars of the right side. Both are from the freshwater deposits of Queensland. The less fragmentary specimen includes rather more than an inch of the diastema in advance of the molars, so much of the outer wall of both maxillaries as includes the malar process, and a small portion of the premaxillaries.

The extent of each molar series is 3 inches 6 lines; they run almost parallel with a slight curve convex outward: the least interspace between the right and left series, viz. at the fore part of the second molar (d_4), is 1 inch; the greatest, viz. at the hind part of the last molar (m_3), is 1 inch 6 lines; the interspace between the right and left anterior teeth (d_3) is 1 inch $2\frac{1}{2}$ lines.

Thus, as in *Phascolomys medius*, the disposition of the upper molars and general form of the intervening palate is after the type of the existing hairy-nosed Wombat; but the concavity, transversely, of the palate is even greater than in *Phascolomys medius*, and becomes still more marked at the diastemal region.

The malar process of the maxillary (Plate XXXV. fig. 2, *zr*) rises at the same elevation above the socket of the third molar as in *Phascolomys medius*, showing a variety amongst the larger extinct Wombats which has been noted in the smaller existing species†.

The prezygomatic ridge (ib. *m*) resembles, in its curved course, length, and narrowness, that in *Phascolomys latifrons*. The maxillary anterior thereto advances and bends

† Philosophical Transactions, 1872, p. 179, figs. 5 & 6.

in with a convexity lengthwise: in the latifront and other living species the bone is here concave in the direction of the skull's axis. As the maxillary in *Phascolomys magnus* proceeds to join the premaxillary, the convexity changes to a concavity, in which remains of the maxillo-premaxillary suture may be traced.

The diastemal border (ib. fig. 2, 21') rises as it advances from the molar alveoli at a less open angle than in *Phascolomys medius*, in which, as in the recent species, it extends forward nearly on the same parallel with the line of the alveolar outlets.

A shallow channel marks the inner surface of the commencement of the diastemal border (ib. fig. 1, 21'), its course being from above obliquely forward; there is a feeble rising of the surface anterior thereto. The palate between the ridges is regularly arched, the span being 1 inch 6 lines, the depth or height of the arch 1 inch. The extent preserved just reaches the place of entry of the prepalatal or "incisive" foramina, showing from the nasal cavity the hind wall of those canals and the increased vertical extent of the free inner surface of the premaxillary, making the sudden deepening of this part of the palate when viewed from below in such specimens as have that part entire, such as the subjects of fig. 2, Plate XXXII., & fig. 2, Plate XXXIII. *a*, from the smaller extinct species, *Phascolomys medius*.

The fractured surface of the premaxillaries (Plate XXXV. fig. 5) exposes the incisors near the apical end of the long pulp-cavity, about 1 inch 3 lines above the diastemal ridge: the premaxillary increases in thickness as it rises to form the alveolus. The upper fractured surface of the present fossil (Plate XXXV. fig. 4) exposes part of the floor of the nasal passages, gradually descending as they retrograde toward the place of the post-palatine apertures. Most of the intermolar floor of these passages and roof of the mouth has been broken away.

On each side of the nasal passages appear the hollow implanted ends of the molar teeth. That of d_3 (fig. 4) projects above the prezygomatic ridge, that of d_4 between this and the front pier of the zygoma (21*); and the relative position of the rest conforms with the generic type of these singular elongate, outwardly curved, ever-growing teeth.

The total length of the first and smallest, following the curve, is 2 inches 9 lines. The long diameter of the oval or subtriangular grinding-surface is 6 lines; the breadth near the base, which is backward, is 5 lines. The inner enamelled side extends forward, with a very slight outward bend, from the axial line of the skull to the apex, which is narrow and obtuse, and round this the enamel bends for a short way along the outer side of the tooth; this is the longest side, and curves from behind forward and inward to the apex more strongly than does the inner side. The enamel can be traced from the inner side over the greater part of the hind surface of the tooth. The coat of cement covering the outer side of the tooth can be traced over parts of the enamel, the whole of which it seems originally to have covered.

The grinding-surface of the second molar (d_4) gives 9 lines in fore-and-aft diameter, 6 lines across the hinder lobe; that of the third molar (m_1) has the same longitudinal

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The grinding-surface of the second molar (d_4) gives 9 lines in fore-and-aft diameter, 6 lines across the hinder lobe; that of the third molar (m_1) has the same longitudinal

with rather less transverse extent; and the two succeeding teeth diminish, chiefly in transverse thickness. The grinding-surface of the last molar (m_3) has a fore-and-aft extent of 6½ lines, with a transverse diameter at the hind lobe of but 3 lines. In shape, implantation, and structure, showing interruption of the enamel coating at the outer side, these upper molars closely adhere to the generic character of *Phascolomys*. The exposed implanted ends show the widely open persistent pulp-cavities. The section of the base of the right incisor has a transverse diameter of 6 lines, a vertical one of 5½ lines. The upper, which would become the front surface, is transversely convex; the under surface is transversely concave, but irregularly so, from the greater production downward of the inner angle. The upper incisor appears, from the present remnant of it, to differ in shape as well as size from that of *Phascolomys medius*. The inner interspace between the pair at the place of fracture (Plate XXXV. fig. 5) is 7 lines; they no doubt converged as they descended to come into contact at their exposed and working ends.

The above-described fossil is from a full-grown and seemingly old individual.

I am glad, however, to have another example of the size of teeth which typifies *Phascolomys magnus*. It is afforded by a fragment of the right maxillary, with the second, third, and fourth molars *in situ*, and portions of the sockets of the first and fifth.

The antero-posterior extent of the grinding-surfaces of the three teeth in place is 2 inches 4 lines, according in all dimensions and in relative size with those in the subject of figs. 1–4, Plate XXXV. The outer surface of the bone shows the same relative position of the malar process of the maxillary, the same shape and course of the prezygomatic ridge, so far as it is preserved. Part of the malar bone contributing to the fore part of the orbit is also here preserved; but the fragment has been much rolled and worn, and is incrusted with the petrified lacustrine deposit.

In both specimens the enamel has a finely reticulate surface, with a tendency to longitudinal striation. This surface aids the attachment of the cement.

Amongst the detached teeth worked out of the portions of breccia from the Wellington-Valley bone-caves transmitted to the British Museum was one entire molar tooth and the halves of two others (Plate XXXV. fig. 6), of the size of those of *Phascolomys magnus*. The entire molar corresponds closely with the third, upper jaw, left side, in the specimen last described from Darling Downs (ib. fig. 1, m_1). We thus get evidence of the former range of *Phascolomys magnus* over some hundreds of miles of the Australian continent.

§ 3. *Phascolomys gigas*, Ow.*—Of the lower jaws of Wombats exceeding in size that of *Phascolomys medius* (Plate XXXIV.), I have seen none with a molar series having the same relative size to the upper one in *Phascolomys magnus* (Plate XXXV.) which the teeth of the lower jaw bear to those of the upper one in existing Wombats, and in all the extinct species of which I possess means of comparing those teeth.

A series of lower molars with an extent of grinding-surface of 4 inches 3 lines (Plate

* Art. "Palæontology," Encyclopædia Britannica, 1858, vol. xvii. p. 175. fig. 114.

XXXVI. fig. 3) cannot have worked, in the same head, upon an upper series of only 3 inches 6 lines (Plate XXXV. figs. 1 & 3). The anterior molar of the lower or movable jaw in *Phascolomys medius* (Plate XXXIV. fig. 2, d_3) has a somewhat smaller extent of grinding-surface, as in all existing Wombats, than the corresponding tooth of the upper or fixed jaw (Plate XXXII. fig. 2, d_3, and Plate XXXIII. fig. 2, d_3). The smallest example of d_3 in the remains of large Wombats yet to be described gives 9 lines and $4\frac{1}{2}$ lines as the two diameters of its almost elliptical grinding-surface (Plates XXXVI. & XXXVII. d_3). Such a tooth cannot have belonged to the same species as the one which has an upper anterior molar with the dimensions above given as characteristic of *Phascolomys magnus* (Plate XXXV. d_3).

Of this species the lower jaw and teeth have not yet come under my observation. All the examples of the large extinct Wombats now before me for description belong to the species *Phascolomys gigas*, of which the grinding-surface of a lower molar is figured in the "Article" quoted above, and in my 'Palæontology' (p. 431, fig. 172, 2nd ed. 1861); the former existence of which Wombat I noticed, some years before, in my second memoir "On the Osteology of the Marsupialia"*.

Satisfactory evidence of this species has since reached me, of which I propose, first, to describe a considerable proportion of the mandible, obtained by EDWARD S. HILL, Esq., from a freshwater deposit at Eton Vale, Darling Downs, in 1863, and presented by Sir DANIEL COOPER, Bart., to the British Museum.

It consists of the right ramus (Plate XXXVI. fig. 1) with the fore part broken off near the socket of the first molar (d_3), and with some mutilation of the outstanding parts of the ascending ramus; also of the fore part of the left ramus (ib. fig. 2), with the hind part broken off at the socket of the penultimate molar (m_2). They are both parts of the same mandible, and I have therefore supplied, in the subjects of Plate XXXVI. fig. 2, Plate XXXVII. fig. 1, and Plate XXXVIII. fig. 1, from one ramus what was wanting in the other.

Reference to Plate XXII. Phil. Trans. 1872, where the side view is given of the mandible in the three known living species of *Phascolomys*, will make at once appreciable the character of the present extinct Wombat, in the minor relative antero-posterior extent of the ascending ramus, and its greater relative height before dividing into the condylar (b) and coronoid (c) processes. The intervening notch sinks nearly to the level of the grinding-surface of the molars in the recent and smaller extinct Wombats; whereas in *Phascolomys gigas* the common plate (f, g) rises much higher before dividing into b and c (Plate XXXVI. figs. 1 & 2). The fore-and-aft extent of the rising branch at the neck of the condyle equals in extent that of the last four molars in *Phascolomys platyrhinus*,

* Trans. Zool. Soc. vol. iii. p. 306, 1845:—"I have recently obtained evidence from the postpliocene deposits of the district of Melbourne, through the kindness of my friend Dr. HOBSON, of an extinct Wombat, or true *Phascolomys*, at least four times as large as either of the known existing species." These were *Phascolomys vombatus* and *Phascolomys latifrons*; the somewhat larger continental Wombat (*Phascolomys platyrhinus*) had not then been determined.

and rather more in *Phascolomys latifrons*; in *Phascolomys gigas* the same dimension equals only the last two molars and half of the antepenultimate one.

The ectocrotaphyte ridge (Plate XXXVI. fig. 1, *h*, *h*) is relatively more prominent and the depression (*f*) which it circumscribes below is relatively deeper in *Phascolomys gigas* than in either the Platyrhine or Tasmanian Wombats, and the intercommunicating vacuity is relatively wider in the gigantic Wombat, in which its long diameter is 9 lines. The neck of the condyle at its origin (*b*) is but 9 lines across; it expands to a breadth of more than an inch where the condyle has been broken off. The base of the coronoid process (*c*) has an antero-posterior extent of 1 inch 3 lines; the anterior margin continued into that of the rising ramus subsides upon the outer surface of the jaw (*q*) below the socket of the penultimate molar (m_2).

The lower contour of the mandible (Plate XXXVI. figs. 1 & 2) describes a strong convex uninterrupted curve to the fractured diastemal part, herein resembling rather the latifront, or hairy-nosed, than the bare-nosed Wombats.

The inflected angle (Plate XXXVIII. fig. 1, *a*) begins, posteriorly, at a lower level than the ectocrotaphyte plate (ib. *h*), as in existing Wombats, but it has a minor relative extent; that of its base, as defined anteriorly by the "mylo-hyoid groove" (Plate XXXVI. fig. 2, *w*), does not exceed 2 inches; consequently the superangular cavity (*e*) is relatively small. The dental canal (Plate XXXVII. fig. 4, *o*) begins as a wide transverse fissure, internal to which is the large vacuity above mentioned leading to the ectocrotaphyte fossa. The postalveolar ridge (ib. *t*) forms a low angle as it bends to the superangular fossa. The ectalveolar groove (ib. *u*) is relatively narrow.

The depth of the horizontal ramus augments more rapidly to the back part of the symphysis (Plate XXXVI. fig. 2, *s*) than in recent or smaller extinct Wombats; from being 2 inches behind the last alveolus it grows to 3 inches 3 lines below the interval between the penultimate and antepenultimate alveoli. The smooth thick lower border shows prominences indicative of the matrices of the hinder molars, the bone being here reduced to extreme thinness. The symphysis begins behind at a vertical line dropped from the interspace between m_1 and m_2; it has been partially obliterated, the separation of the rami here being attended with fracture of the confluent portion. This indicates an aged animal. The hinder and upper border of the symphysis is divided into two curves by the encroachment of the smooth inner surface of the ramus a little below the swelling (i^*) indicative of the closed and formative end of the socket of the incisor. The interlocking rough narrow ridges of the joint show the usual tendency to radiate from above downward. There are two anterior outlets of the dental canal (in the subject of Plate XXXVI. fig. 1, *v*) on the same vertical line, about half an inch in advance of the alveolus of d_3 and near the diastemal margin.

The length of the "ascending ramus" before dividing into the condylar and coronoid processes shows a resemblance in the gigantic Wombat to the large herbivorous Notothere and Diprotodon, which is not seen in the smaller species of *Phascolomys*. The bold curve of the lower contour of the "horizontal ramus" in *Phascolomys gigas* recalls

that feature of the mandible of the Megathere, and it has a like relation to the lodgement of the formative matrices of long, ever-growing molars *.

The first molar (ib. figs. 1 & 3, d_3) is subbilobed, through opposite longitudinal shallow grooves equally dividing the tooth. The tendency to a gain of grinding-surface in the direction of the jaw's axis seen in the same tooth of *Phascolomys medius* is in the larger species carried further, so as to substitute for the representative of one half or lobe of the succeeding molars in the anterior one of smaller Wombats a more simplified condition of the normal bilobed phascolomydian type of molar. The enamel of d_3 in *Phascolomys gigas* is continued from the outer over the front side, and along nearly the whole of the hind side of the tooth. A coat of cement of similar thickness covers the inner side, and is continued more thinly upon the enamel. The surface of the enamel is longitudinally rugoso-striate.

All the succeeding molars have a partial coat of enamel, extending from the outer side upon the fore part to where this comes into contact with the antecedent tooth, and continued, perhaps, a little further upon the hind surface. The rest of the dentine has the coating of cement. The proportions of the several teeth are shown in the figures above cited.

As before remarked, the smaller size of the last molar indicates the Latifront Wombat to be nearer akin to the extinct giant than are the bare-nosed living species. The same affinity is shown by the small size of the lower incisors in *Phascolomys gigas* (Plate XL. figs. 1, *ï*, 2, 3, 4). They are smaller, especially narrower, in *Phascolomys latifrons* than in *Phasc. platyrhinus* and *Phasc. vombatus*, and are, relatively, still smaller in *Phasc. gigas*, with a distinctive shape. But the characters of the lower pair of incisors are better shown in another mandibular specimen of the present large species.

The section or transverse fracture of the hollow base of the right incisor is shown in Plate XXXVII. fig. 2, *i*; the length and curvature of the implanted part of the second molar (d_4) are seen in the same figure, in which *e e* indicates the anterior terminal line of the outer enamel. The hinder fracture of the left ramus of the same jaw (ib. fig. 3) shows the length and curve of the penultimate molar (m_2), and the posterior terminal line of its partial covering of enamel (*e*).

Of the above-described instructive specimen of *Phascolomys gigas* little more than an inch of the diastemal part of the jaw is preserved (Plate XXXVI. figs. 1 & 2, *l*). Fortunately, the first specimen which made known to me the fact of so large a Wombat having formerly existed in Australia included 2 inches 8 lines of the diastemal part of the jaw, which contracts rapidly to the terminal outlets of the incisive alveoli (Plate XXXIX. figs. 1 & 2); whence I conclude that but little had been broken away from that end of the mandible.

* Should any successor deem the differential characters of the giant Wombat of generic or subgeneric value, as the minor differences of *Phascolomys latifrons* have been by Dr. MURIE (Proc. Zool. Soc. 1867, p. 815), they may, perhaps, accept the name '*Phascolonus*,' having reference to the size of this species, which equalled that of the Wild Ass.

The subject of Plate XXXIX. figs. 1, 2, 3 was obtained from "a salt-lake, nearly 100 miles west of Melbourne," and was transmitted to me by Dr. HOBSON*. It is the symphysial end of the mandible, with 4½ inches of the joint (*s*, *s'*), the obliteration of which indicates the age of the individual; it includes the implanted parts of the incisors (*i'*), and of the three anterior molars of each ramus (fig. 1). The under part of the symphysis (fig. 2, Plate XXXIX.) shows the pair of subsymphysial foramina (*r*) in the same relative position as in the existing Wombats (ib. fig. 4, *r*). The prolongation of the attenuated anterior end of the mandible shows a nearer resemblance in *Phascolomys gigas* to *Phascolomys latifrons* (Phil. Trans. 1872, Plate XXIII. fig. 3) and *Phascolomys Krefftii* (ib. Plate XX. fig. 2) than to *Phascolomys platyrhinus* (ib. Plate XIX. fig. 2) or to *Phascolomys vombatus* (ib. fig. 1). The upper surface of the specimen (Plate XXXIX. fig. 1) shows the same concavity between the right and left anterior molars as in the more perfect specimen of *Phascolomys gigas* (Plate XXXVII.). The hollow implanted ends of the incisors (Plate XXXIX. figs. 1 & 3, *i'*), exposed by fracture of the fossil, hold the same relative position to the third molars (m_1) as in the more complete mandible. The anterior outlets (ib. fig. 1, *v*, *v*) of the dental canal are in the same position.

The subject of fig. 5, Plate XL., shows a slight inferiority in the size of the molar teeth as compared with that of figs. 1, 2, & 3, Plate XXXVI. The present fossil is a portion of the left ramus with the last four molars in place. The longitudinal extent of their grinding-surfaces is 3 inches 5 lines (Plate XL. fig. 5), as against 3 inches 6 lines (Plate XXXVI. fig. 3); that of the first three molars is the same in both specimens, and the difference is due to a smaller size of the last molar in the present (Plate XL. fig. 5, m_3), the hind lobe of which also shows a longitudinal indent. I am unwilling to regard this as signifying more than a variety of *Phascolomys gigas*. The features of the mandible, such as the anterior origin of the ectocrotaphyte ridge (ib. fig. 6, *h*), and of the ascending ramus (ib. fig. 6, *g*), as also the ectalveolar groove (ib. fig. 5, *u*) and postalveolar ridge (ib. ib. *t*), so far as they are preserved, closely resemble those of the more complete specimen of mandible of the present large species.

The fourth example of *Phascolomys gigas* I know through a cast and photograph of the original, now in the Australian Museum, Sydney, New South Wales. The cast was prepared by direction of the Trustees of that Museum, and was transmitted as a donation to the British Museum. A photograph of the natural size, showing the grinding-surface of the molar teeth, was forwarded to me through the same liberality. The specimen is a portion of the right ramus, including the series of five molars and the entire incisor (Plate XL. figs. 1–4), of which tooth a separate cast was prepared and transmitted. The molars show a slight superiority of size over those in the subject of Plate XXXVI., as may be seen by comparison of figs. 3 & 4 in that Plate; but this I take to be within the limits of individual or sexual range of size. The configuration of the ramus, so far as the comparison can be made, closely resembles that of the more complete mandibles of the present species (Plates XXXVI., XXXVII., & XXXIX.): the portion of the

* Letter from Dr. HOBSON, March 3rd, 1844.

ectocrotaphyte cavity preserved in the present cast indicates the same depth; the symphysial articular surface (Plate XL. fig. 1, s, s') has the same shape and extent; the molar teeth (ib. fig. 1, d_3, d_4, $m_{1,2,3}$) show the same configurations and proportions of their grinding-surface (Plate XXXVI. fig. 4)—the extent of the series is 4 inches 7 lines. The length of the incisor (Plate XL. figs. 1, $\ddot{\imath}$, & 2) is 7 inches, its vertical diameter is 8 lines, its transverse diameter 6 lines. The section of the tooth (ib. fig. 4) is lozenge-shaped, with the four angles rounded. The lateral angles (e, e') are nearer the upper (u) than the lower (o) angles, and the lower inner facet (g) is broader than the lower outer one (h); the convergence of the two broad lower facets to the obtuse lower angle makes that part of the incisor the narrowest or smallest: if the angles were rounded off, the shape of the transverse section would be an oval with the large end upward. The upper and inner angles are less rounded and more marked than the outer and lower angles. Two low narrow ridges traverse lengthwise the inner and lower facet (ib. fig. 1, g, g), dividing it into three tracts, the lowest being the narrowest; the outer and lower facet (ib. fig. 2, h, h) is slightly hollowed. A thin layer of enamel coats the lower and lateral parts of the tooth up to the lateral angles (e, e'), where it subsides abruptly after becoming thinner than it was below.

The base of the incisor in the left ramus of the first-described jaw of *Phascolomys gigas* (Plate XXXVI. figs. 1 & 2, $\ddot{\imath}$, and Plate XXXVII. fig. 2, i) repeats the characters above given from the cast of the entire incisor, the original of which is in the Australian Museum; the outer lateral angle is more sharply marked at the implanted part of the incisor compared.

The contrast in the shape and relative size of the incisor of the giant Wombat with that of the largest known living species (*Phascolomys platyrhinus*) is great. The section of the incisor in that species has an area double that of the section of the first molar; in *Phascolomys gigas* these proportions are almost reversed. The long diameter of such section of the incisor is transverse in *Phascolomys platyrhinus*; it is vertical in *Phascolomys gigas.* Amongst living Wombats an approach to the extinct giant is made by the *Phascolomys latifrons*, in which the vertical diameter prevails in the section of the incisor—only the large end of the oval, or base of the triangle, is below, not above as in *Phascolomys gigas*; and the area of the section in *Phasc. latifrons* rather exceeds that of the anterior molar, d_3. In the extinct *Phascolomys medius* (Plate XXXIV. fig. 4, $\ddot{\imath}$) we have a nearer approach to the characters of the lower incisors in *Phascolomys gigas.*

Another evidence of *Phascolomys gigas* is the hind part of the right mandibular ramus with a more mutilated "ascending branch" than in the subject of Plate XXXVI.; it includes the sockets of the last four molars and the base of that of the incisor. The teeth in this specimen must have presented the size of those in the subject of fig. 4 (ib.); the longitudinal extent of the last three sockets is 2 inches 10 lines. The hind fracture is at the intercommunicating canal (Plate XXXVII. fig. 4, p), exposing the wide beginning of the dental canal (ib. o), with its larger division continued along the outer side of the bases of the molar alveoli, and the smaller division (o') extending along the

inner side to emerge at the anterior dental outlet (v); the "mylo-hyoid groove" is broader and less deep than in Plate XXXVI. fig. 2, w. The characters of the ectalveolar groove, of the postalveolar ridge, and of the ectocrotaphyte fossa (f) agree with those of the type mandible of *Phascolomys gigas*.

The present specimen was discovered by M. SATCHE ST. JEAN, at St. Jean Station, Queensland, in the bed of a tributary creek of the Condamine River.

The last specimen which I have now to notice was obtained by F. NICHOLSON, Esq., from the same freshwater deposits at Clifton Plains, Darling Downs, Queensland. I am indebted to the kindness of Professor HARKNESS, of Queen's College, Cork, for the opportunity of here describing and figuring it. It either exemplifies the largest observed variety of *Phascolomys gigas*, or indicates a still larger species, *i. e.* one in which modifications of the shape of the jaw may be associated with its superiority of size. Of this the mutilated state of the fragment does not permit me to judge, and I am disposed to refer the specimen to a large old male of *Phascolomys gigas*.

The longitudinal extent of the outlets of the last three molars of Mr. NICHOLSON's fossil (Plate XXXVIII. fig. 4, $m_{1,2,3}$) is 3 inches 1 line; they show the same kind and degree of decrease of size from the first to the third as in the smaller examples of the species. The breadth and apparent depth of the ectalveolar groove (ib. figs. 3 & 4, u) are as in the first-described mandible (Plates XXXVI. & XXXVII.). The fore part of the base of the coronoid or ascending ramus (ib. fig. 3, g) and of the ectocrotaphyte ridge (ib. h) show likewise the same relative positions. On the inner fractured side of this specimen the large inner division of the dental canal is seen about 9 lines above the closed ends of the last two alveoli.

§ 4. *Conclusion.*—In the case of *Phascolomys*, as of most Mammalian genera, when due time and pains are applied to the acquisition and study of the fossil evidences, the number of species which have passed away is found to exceed that of the living ones which remain.

Until comparatively lately the Wombat was known to zoologists as a solitary exceptional form of small Tasmanian marsupial, peculiar in its scalpriform dentition combined with burrowing habits*. We now know this generic form under many specific structural modifications, and with gradations of bulk rising from that of a Marmot to that of a Tapir.

The rodent type of incisors, both as to number and kind, are retained in all, certainly in the lower jaw of the gigantic species; but it would not be safe to infer that the subjects of the present Paper burrowed like the smaller living Wombats.

If we knew the Hare (*Lepus timidus*) only by fossil remains, we should err in attributing to it the habits and mode of life of the smaller species, *Lepus cuniculus*. It is probable that the larger extinct Wombats did not conceal themselves under ground.

What we know is, that of the series of forms specifically varying the generic type of *Phascolomys* the larger ones have perished. Here, as in the case of the gigantic wingless birds of New Zealand, size and bulk seem to have been a disadvantage in the

* Hence the synonym, *Phascolomys fossor*, of WAGNER.

"contest for existence"*. The small burrowing Kivis†, like the small Wombats, have survived. *Phascolomys gigas* and *Phascolomys magnus* are not likely to have escaped observation if they still lingered in any of the localities made known by the adventurous explorers of Australia; but the diminutive *Phasc. parvus* may yet be found living in some part of that continent.

Another inference, or tributary illustration of a general law, is shadowed forth less plainly, perhaps, than that bearing upon the "battle of life."

The majority of the fossils of common-sized Wombats exemplify, as in the case of *Phascolomys Mitchelli*, the more generalized structure; osteological characters, now distinguishing respectively the hairy-nosed and bare-nosed Wombats, are combined in the skull of that extinct species. At the same time divergent courses of variation had reached the stages indicated by *Phascolomys latifrons* and *Phascolomys platyrhinus* at a period when the larger species, now extinct, appear to have been living in Australia. This is less ambiguously shown, as to time, by the mandible of the continental bare-nosed Wombat from Queensland, than by that of the hairy-nosed species from the breccia of the Wellington-Valley Caverns; for, with regard to specimens obtained from caves, there are grounds of uncertainty as to contemporaneity of introduction not affecting, at least in the same degree, the fossils from stratified deposits of known geological age.

The extirpating cause of the larger Wombats, especially if they were unable to take refuge and conceal themselves under ground, was probably the hostility of man. No human remains, however, or weapons have yet been discovered in the substalagmitic breccias of the caves or in the freshwater deposits of Australia. But as the unseen planet is inferred by evidence of its force, so may the destroyer be conjectured and his discovery anticipated by the effects of his power; such, *e. g.*, as the disappearance of species which, from their easier detection, capture, or bringing to bay, and greater profit when slain, would be the first objects of chase to the primitive Aborigines.

Table of Localities of Fossils of *Phascolomys*, showing:—

Where found.	By whom.	Date.	Species.
Breccia-cavern, Wellington Valley	Sir Thomas L. Mitchell, C.B.	[illegible]	[illegible]
Lacustrine deposits, Victoria	E. C. Hobson, M.D.	[illegible]	[illegible]
Lacustrine deposits, Queensland	Geo. Bennett, M.D., F.L.S.	[illegible]	[illegible]
King's Creek, Darling Downs	Mr. Turner	[illegible]	[illegible]
Gowrie, Darling Downs	Fred. Neville Isaac, Esq.	[illegible]	[illegible]
Eton Vale, Darling Downs	Edward S. Hill, Esq.	[illegible]	[illegible]
St. Jean Station, Darling Downs	M. Satche St. Jean	[illegible]	[illegible]
Drayton, Darling Downs	Sir D. Cooper, Bart.	1864	*Ph. Thomsonii*, *Ph. medius*, *Ph. magnus*, *Ph. gigas*.
Clifton Plains, Darling Downs	F. Nicholson, Esq.	1866	*Ph. gigas*.
Breccia-cavern, Wellington Valley	Prof. Thomson, and Gerard Krefft, Esq.	1867	*Ph. Mitchelli*, *Ph. Krefftii*, *Ph. latifrons*, *Ph. medius*.

* Owen, "On Dinornis," Part IV., Trans. Zool. Soc. vol. iv. (1850) p. 15.

† *Apteryx australis*, Shaw *Apteryx Owenii*, Gould.

EXPLANATION OF THE PLATES.

PLATE XXXII.

Fig. 1. Base of skull and working-surface of the teeth of the upper jaw, *Phascolomys latifrons.*

Fig. 2. Part of base of skull, with working-surface of some molar teeth, *Phascolomys medius.*

Fig. 3. Left side view of the same fossil.

Fig. 4. Right side of fore part of the same fossil.

Fig. 5. Front view of premaxillary part of the same fossil.

Fig. 6. Fractured surface of ditto, showing transverse section of the implanted part of the incisors, *i*, *i*.

Fig. 7. Inner side view of the crowns of the three anterior molars and fore lobe of the fourth molar of the same fossil.

PLATE XXXIII.

Fig. 1. Base of skull and working-surface of the teeth of the upper jaw, *Phascolomys platyrhinus.*

Fig. 2. Part of base of skull, with fractured and working-surface of some molar teeth, *Phascolomys medius.*

Fig. 3. Left side view of the same fossil.

Fig. 4. Posterior fractured end of the same fossil.

Fig. 5. Front view of premaxillaries and fractured incisors of the same fossil.

Fig. 6. Inner side view of exposed part of the three anterior molars and fore lobe of the fourth molar of the same fossil.

PLATE XXXIV.

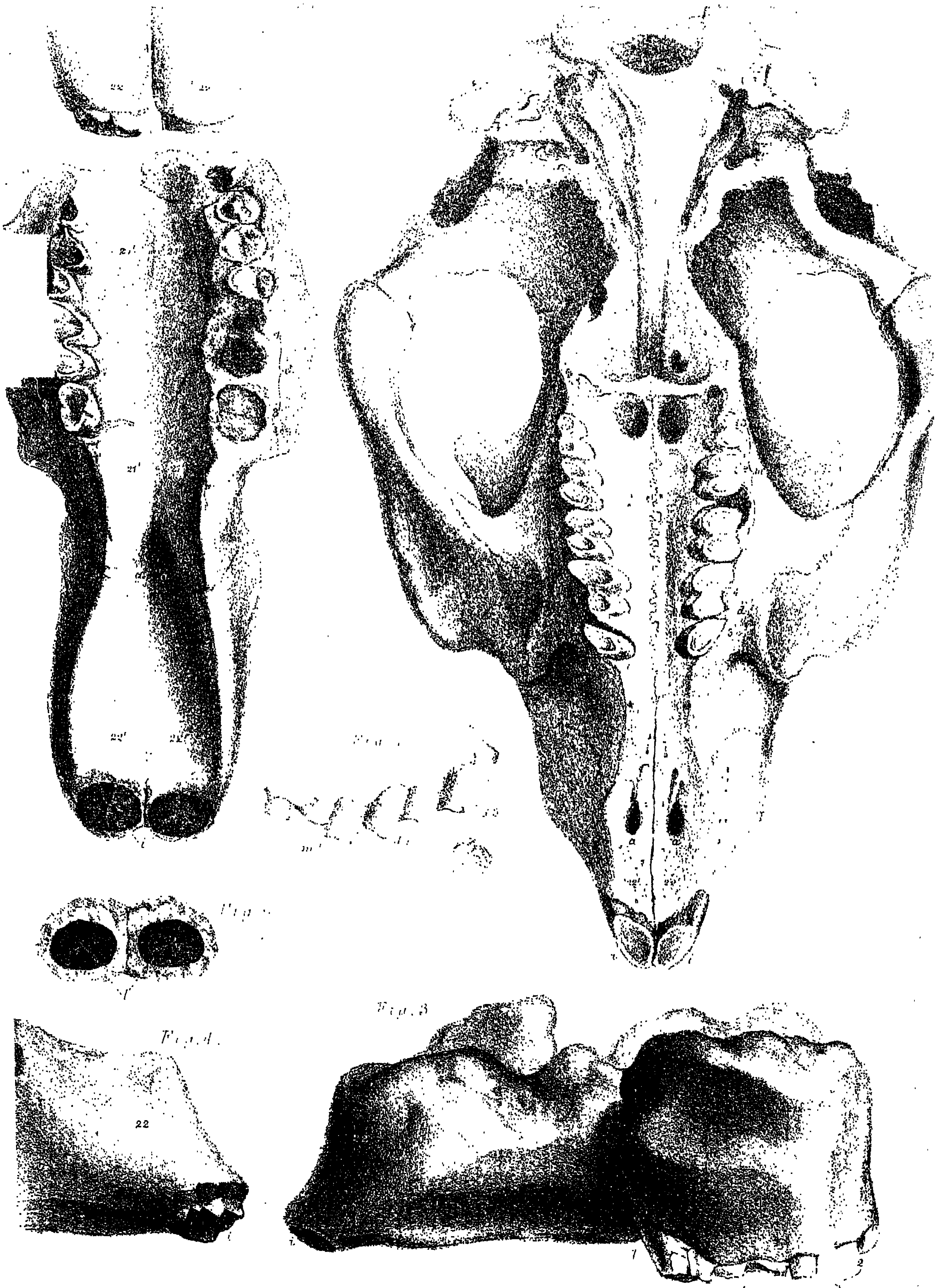
Fig. 1. Outside view of portion of right mandibular ramus, *Phascolomys medius.*

Fig. 2. Inner side view of the same fossil.

Fig. 3. Upper view and grinding-surface of molar teeth of a mutilated mandible of *Phascolomys medius.*

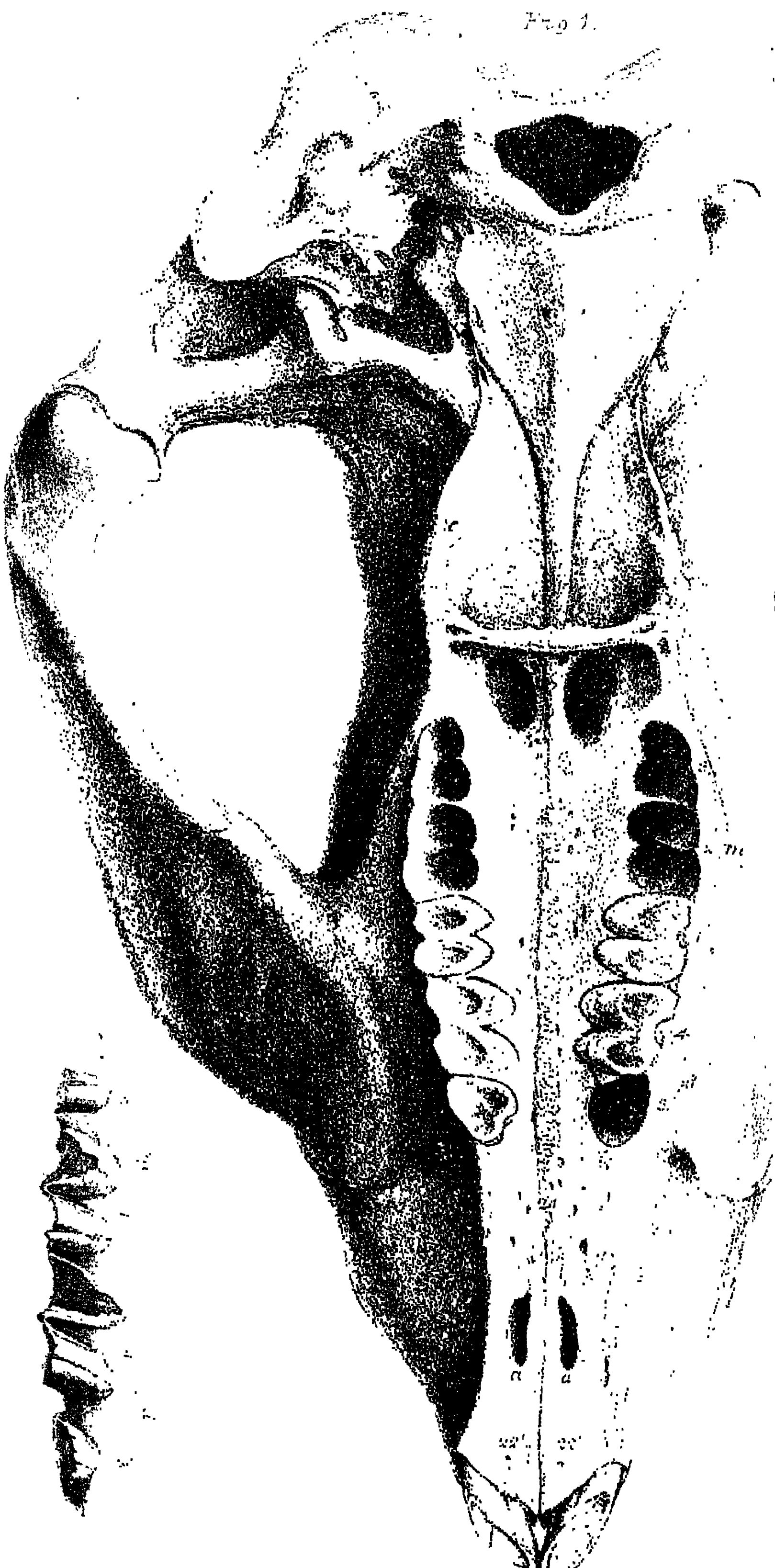
Fig. 4. Front fractured end, with section of implanted part of the lower incisors of the same fossil.

Fig. 5. Hind fractured end of left ramus of the same fossil.



W.West & Co. lith

Fig. 1.



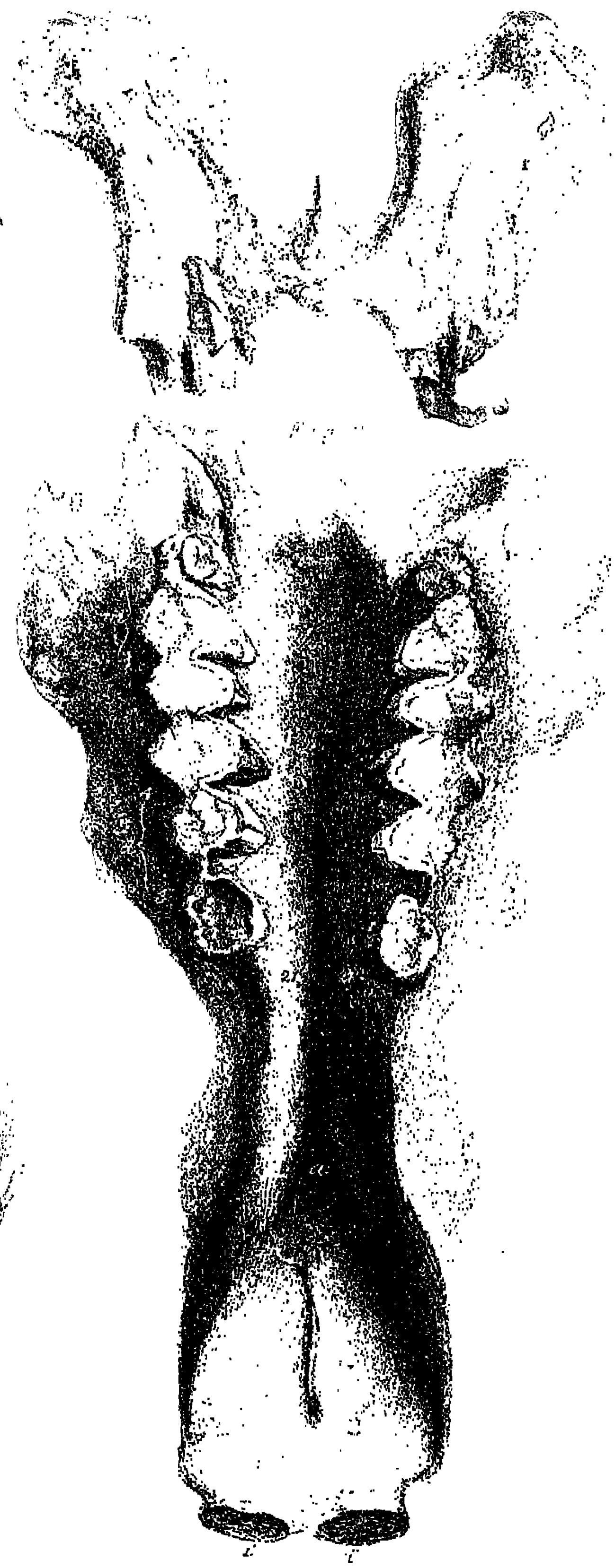


Fig. 5.

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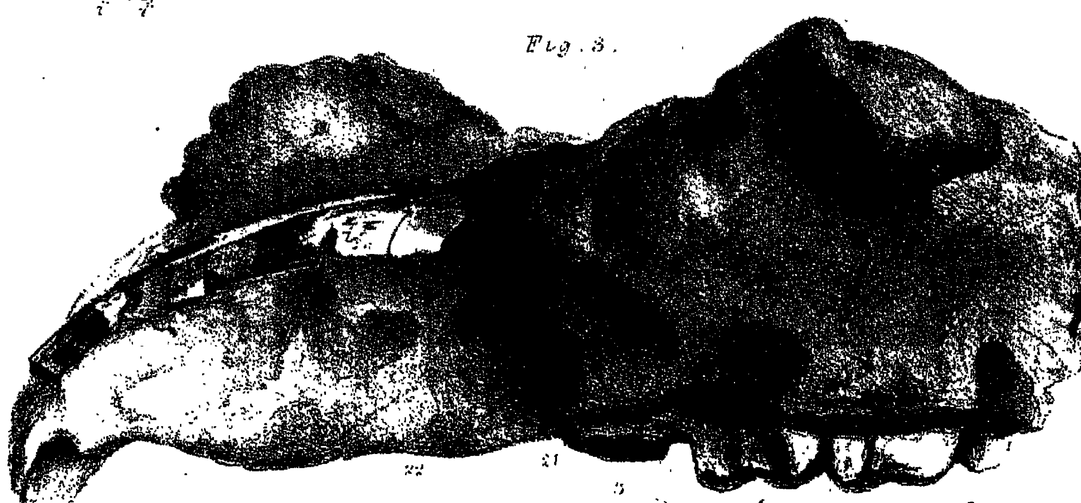

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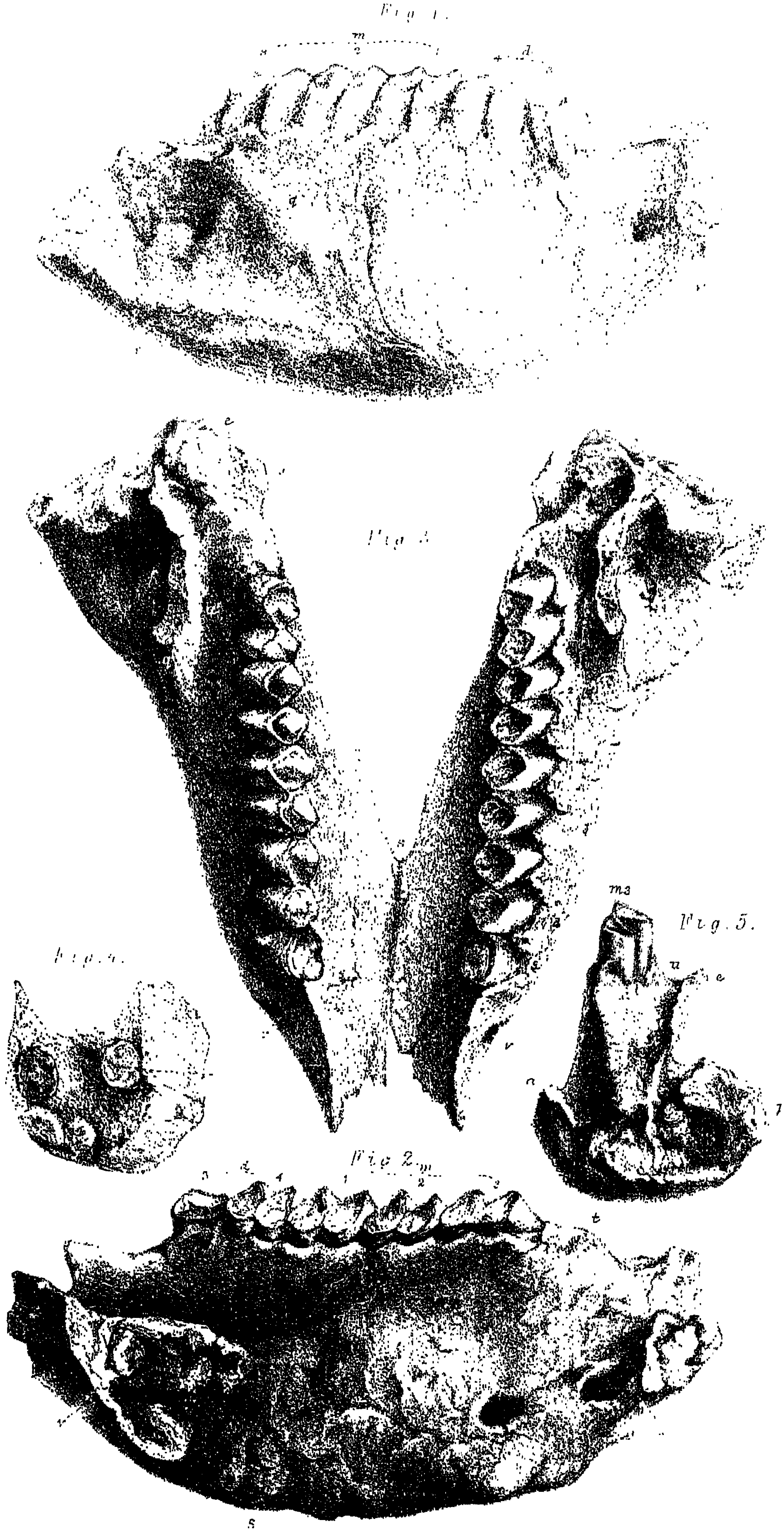
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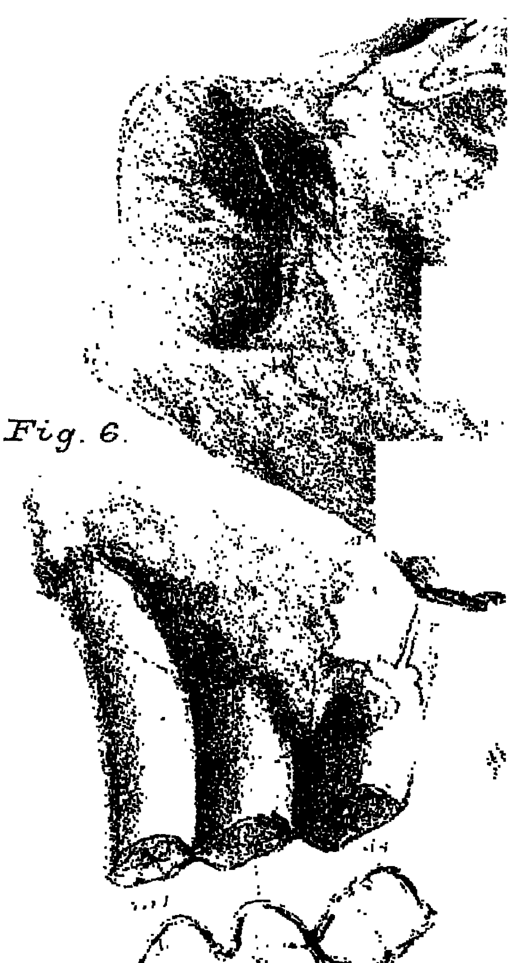
Fig. 6.



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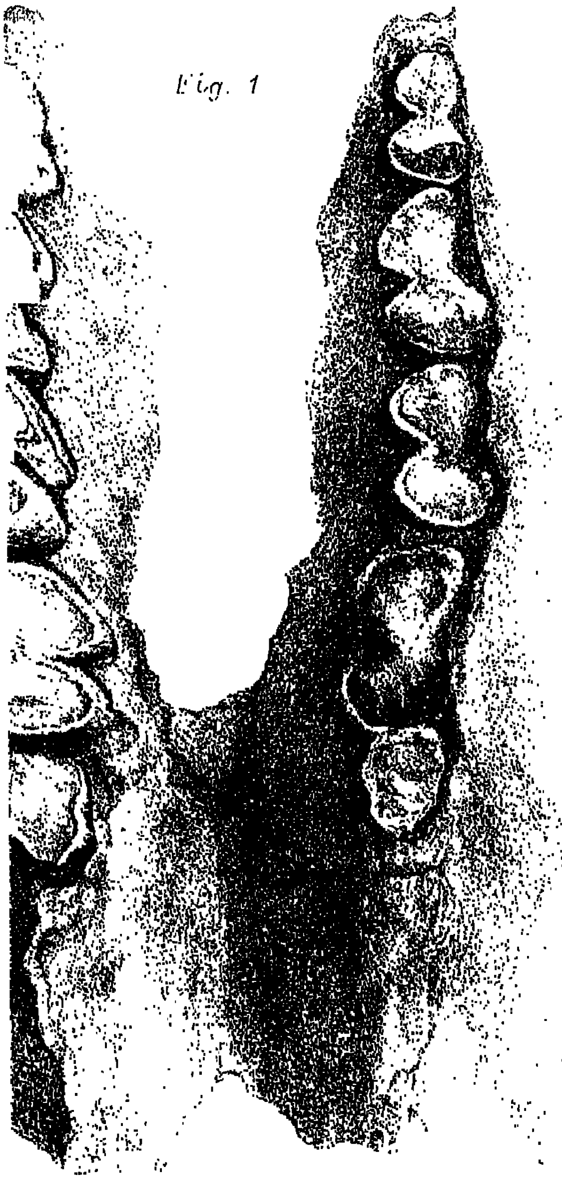

Fig. 4.

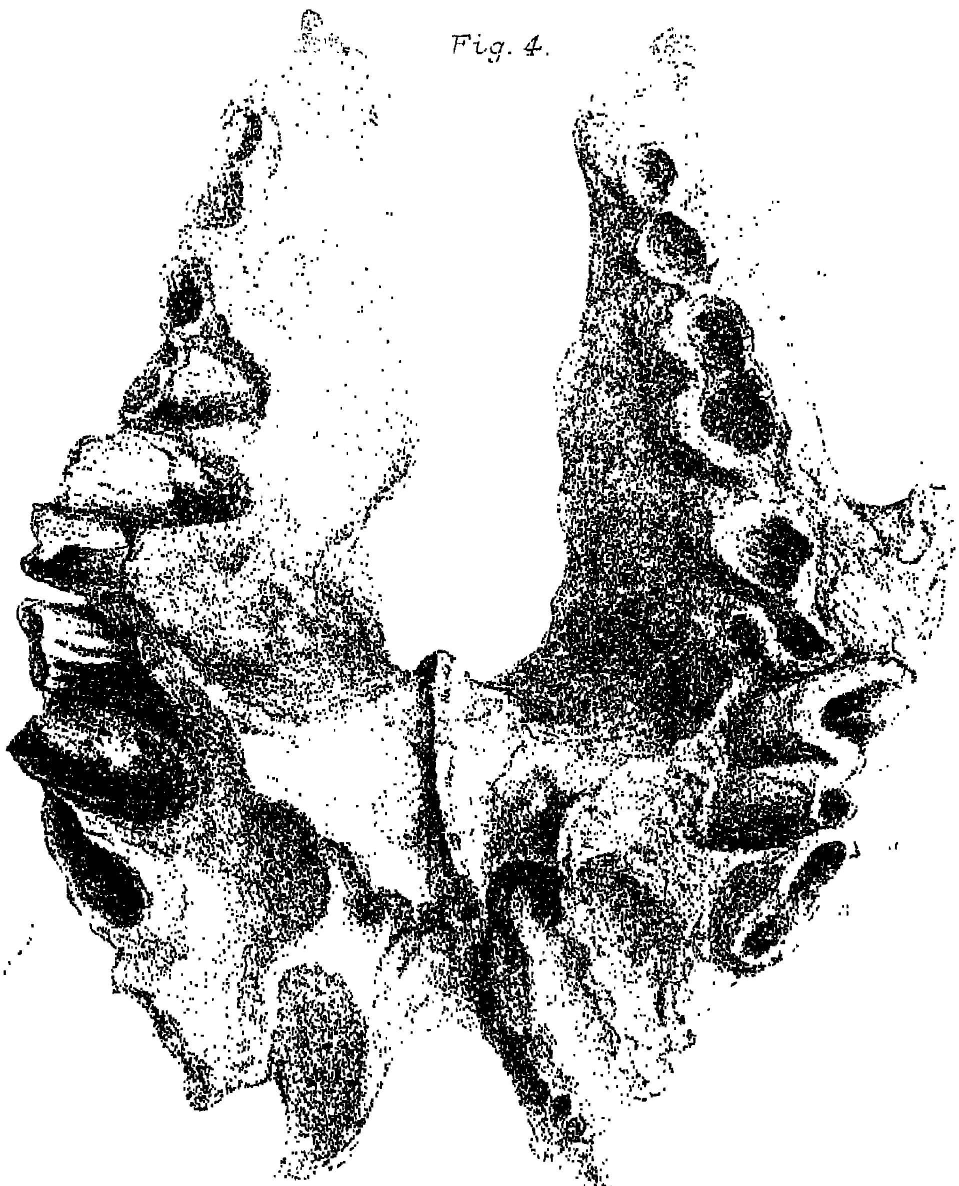

Fig. 5.

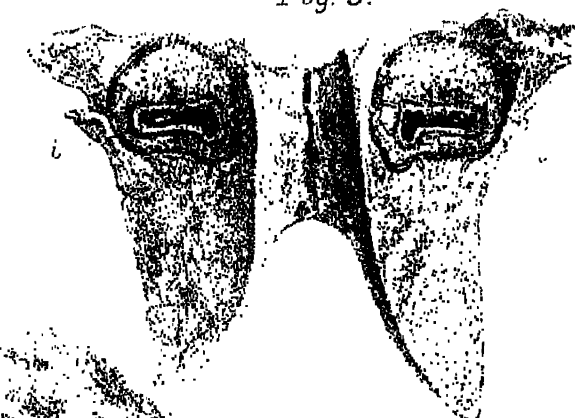

Fig. 2.

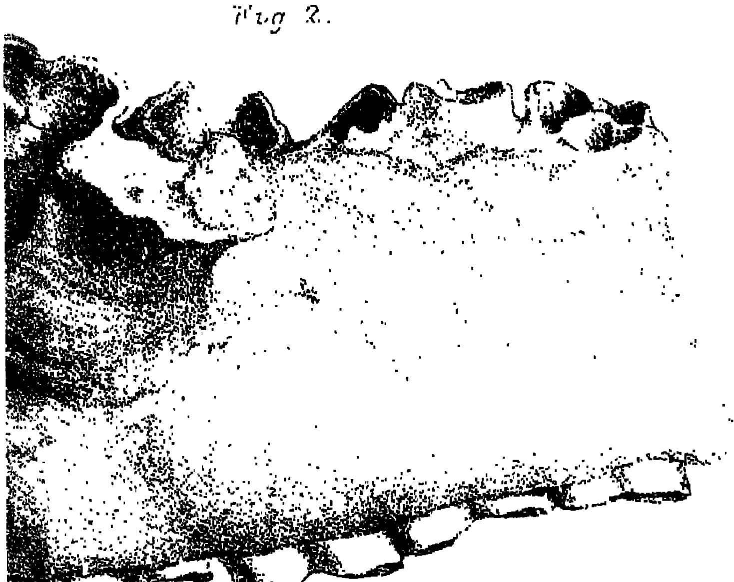

Fig. 7.

Fig. 3.

W. West & Co. lith.

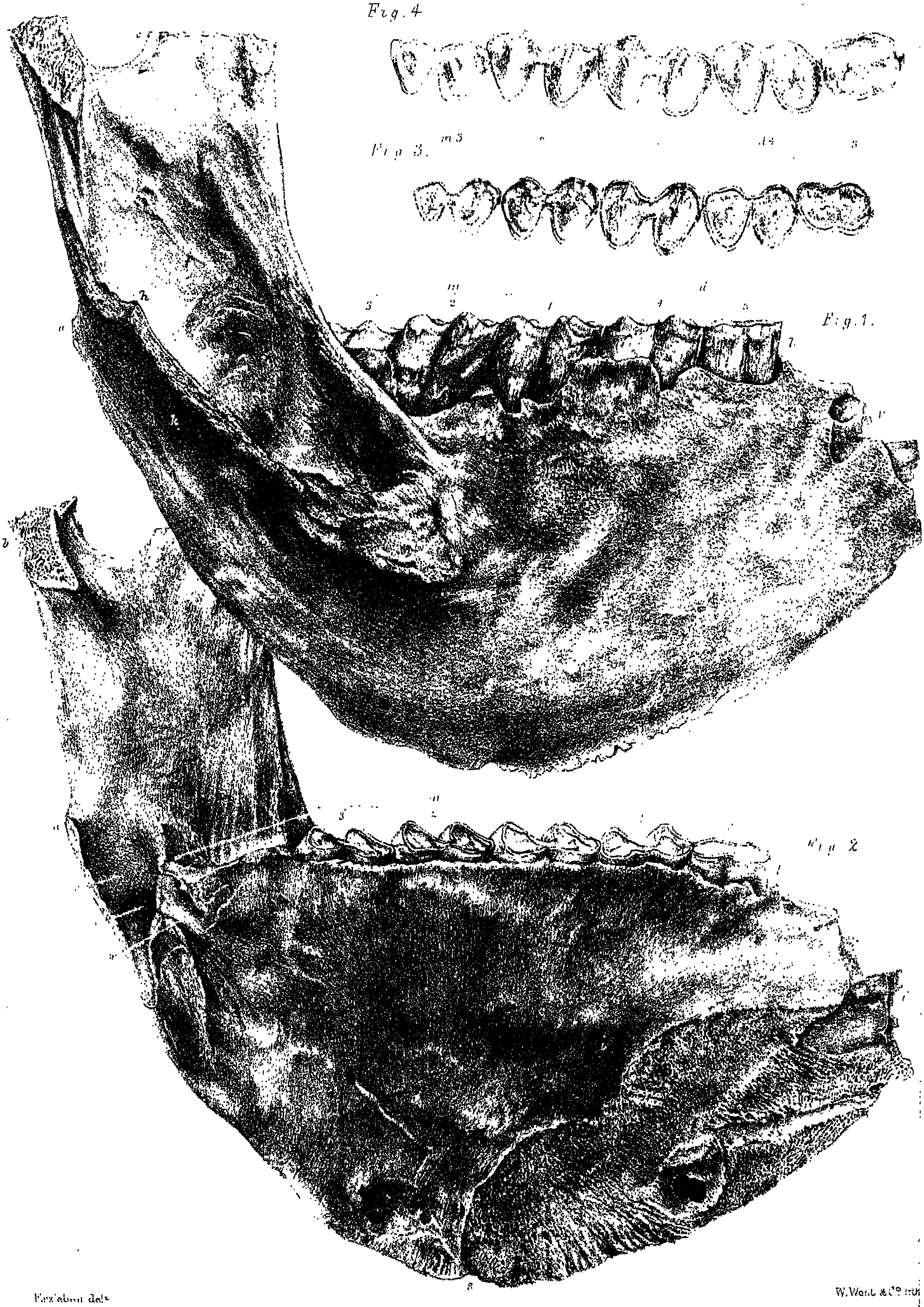

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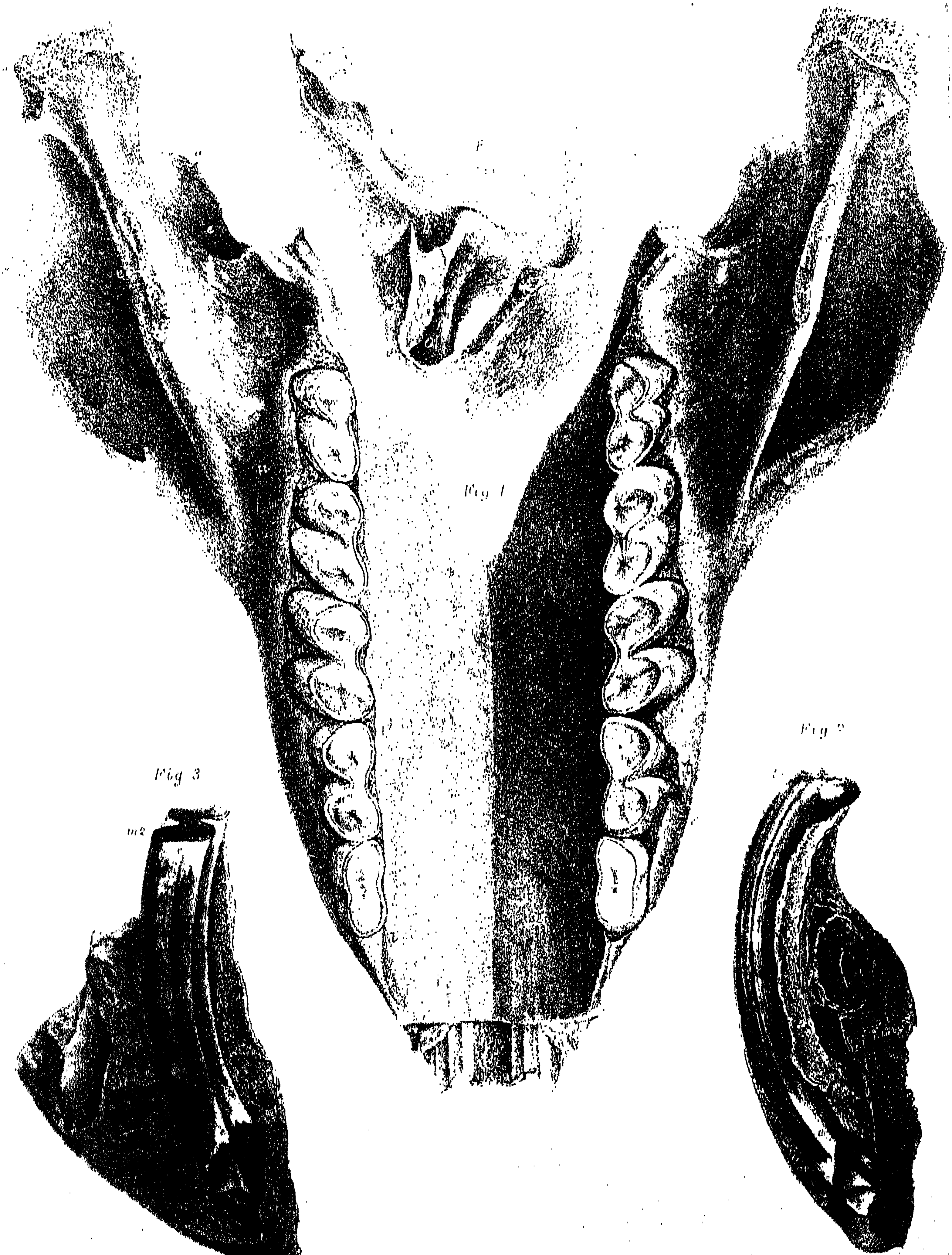
Fig 4.

Fig 1.

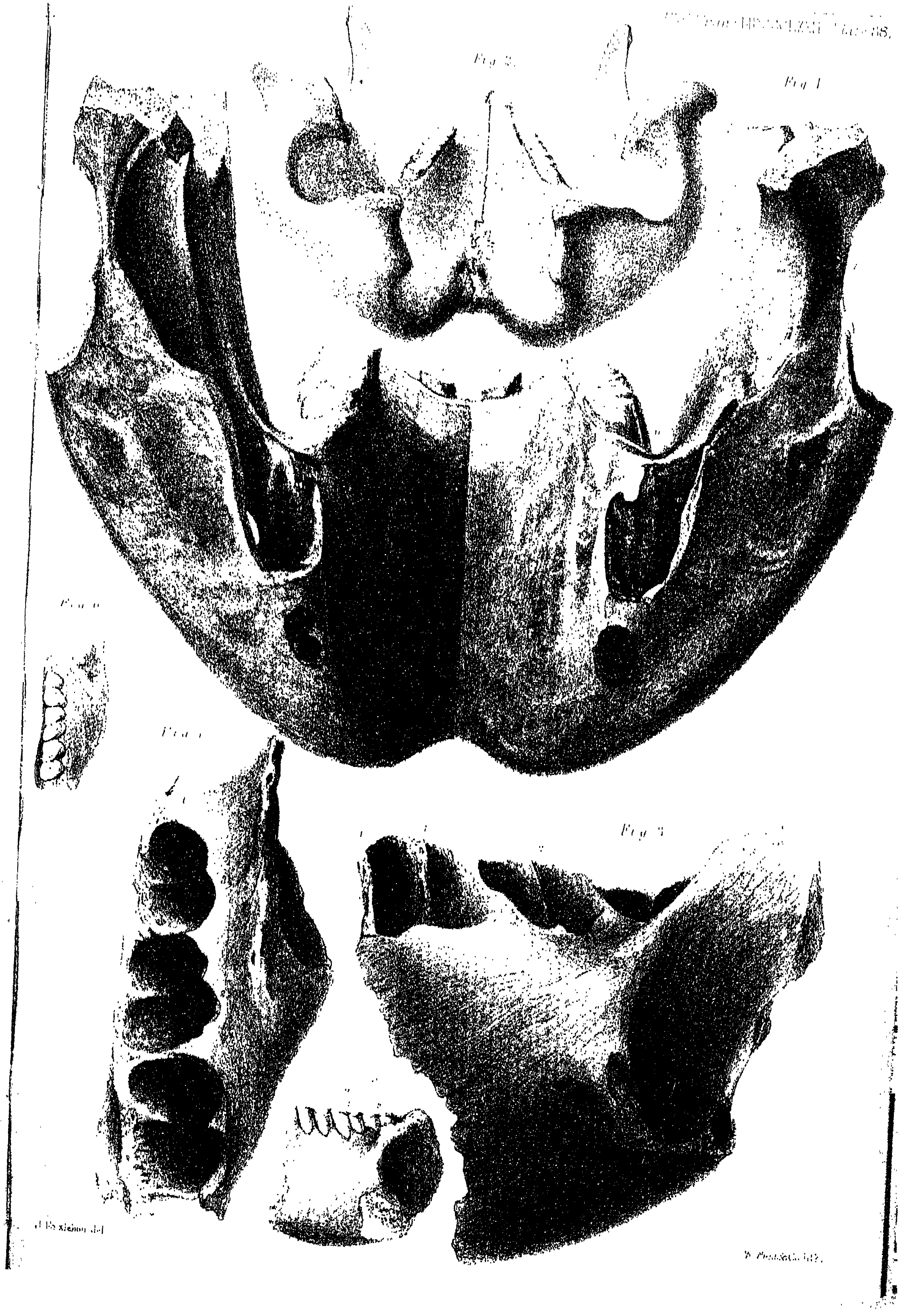
Fig 3.

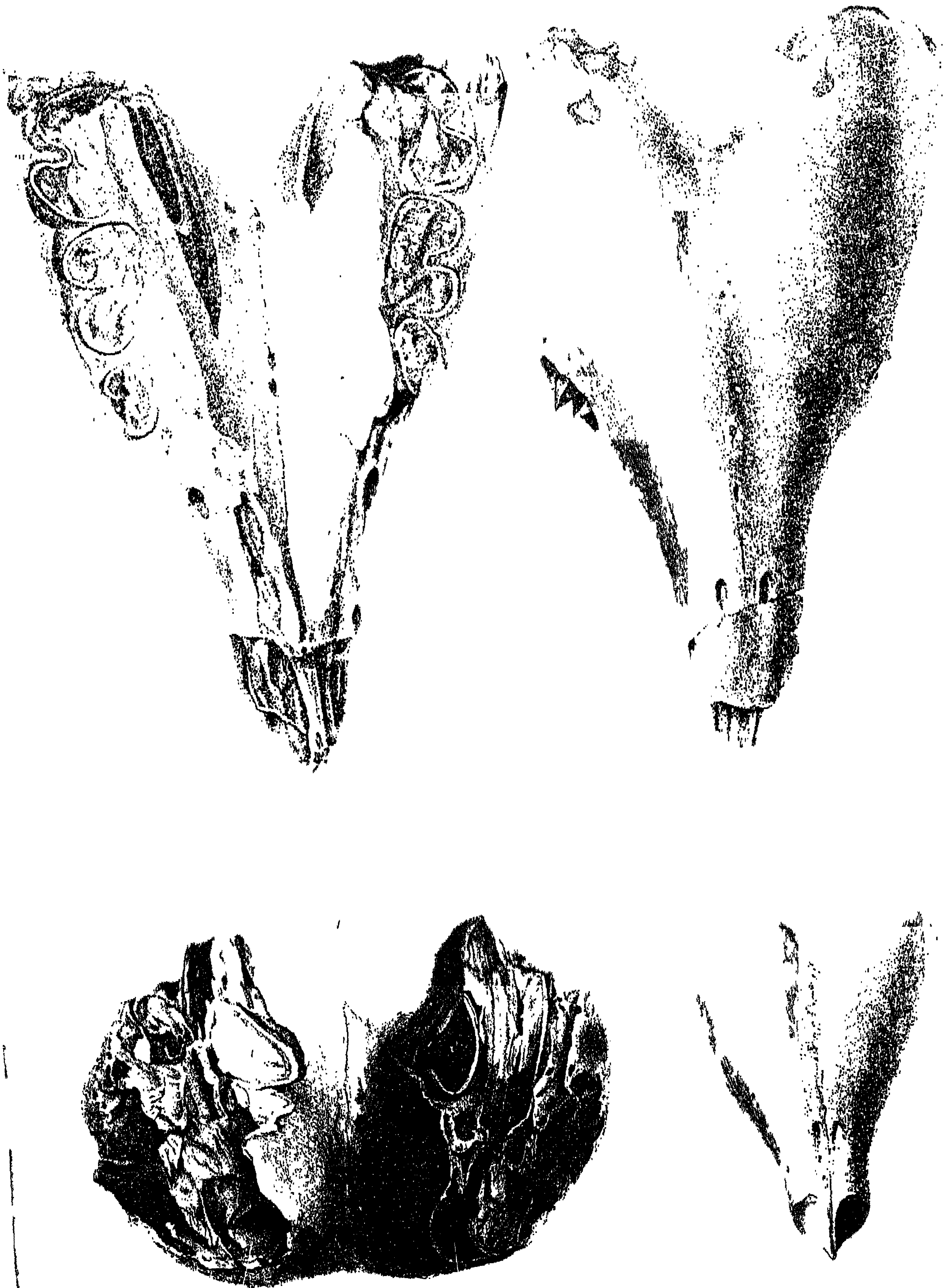
Fig 2.



W. West & C° lith.

Owen.





J. Erxleben del.

W. West & Co. lith.

PLATE XXXV.

Fig. 1. Under view of part of upper jaw and molar teeth, *Phascolomys magnus*.
Fig. 2. Left side view of the same fossil.
Fig. 3. Inner side view of the right molars of the same fossil.
Fig. 4. Upper view of the same fossil.
Fig. 5. Anterior fractured surface of the same fossil, with sections of the base of the incisors, *i*, *i*.
Fig. 6. Third molar and hind half of second molar, *Phascolomys magnus*: the working-surface is shown below.
Fig. 7. Part of upper jaw, with molar teeth, *Phascolomys medius* (from a photograph).

PLATE XXXVI.

Fig. 1. Outside view of part of the right mandibular ramus and teeth, *Phascolomys* (*Phascolonus*) *gigas*.
Fig. 2. Inside view of part of left ramus and teeth of the same mandible.
Fig. 3. Working-surface of the right molars of the same mandible.
Fig. 4. Working-surface of the right mandibular ramus of a larger *Phascolomys gigas*.

PLATE XXXVII.

Fig. 1. Upper view of the lower jaw and teeth, *Phascolomys* (*Phascolonus*) *gigas*.
Fig. 2. Anterior fractured surface of right ramus of the same jaw.
Fig. 3. Posterior fractured surface of right ramus of the same jaw.
Fig. 4. Posterior fractured surface of another mandibular ramus, *Phascolomys gigas*.

PLATE XXXVIII.

Fig. 1. Hind view of mandible, *Phascolomys* (*Phascolonus*) *gigas*.
Fig. 2. Hind view of mandible, *Phascolomys latifrons*.
Fig. 3. Portion of left mandibular ramus of a large *Phascolomys gigas*.
Fig. 4. Upper surface of the same fossil.
Fig. 5. Portion of left mandibular ramus, *Phascolomys parvus*.
Fig. 6. Upper surface of the same fossil.

PLATE XXXIX.

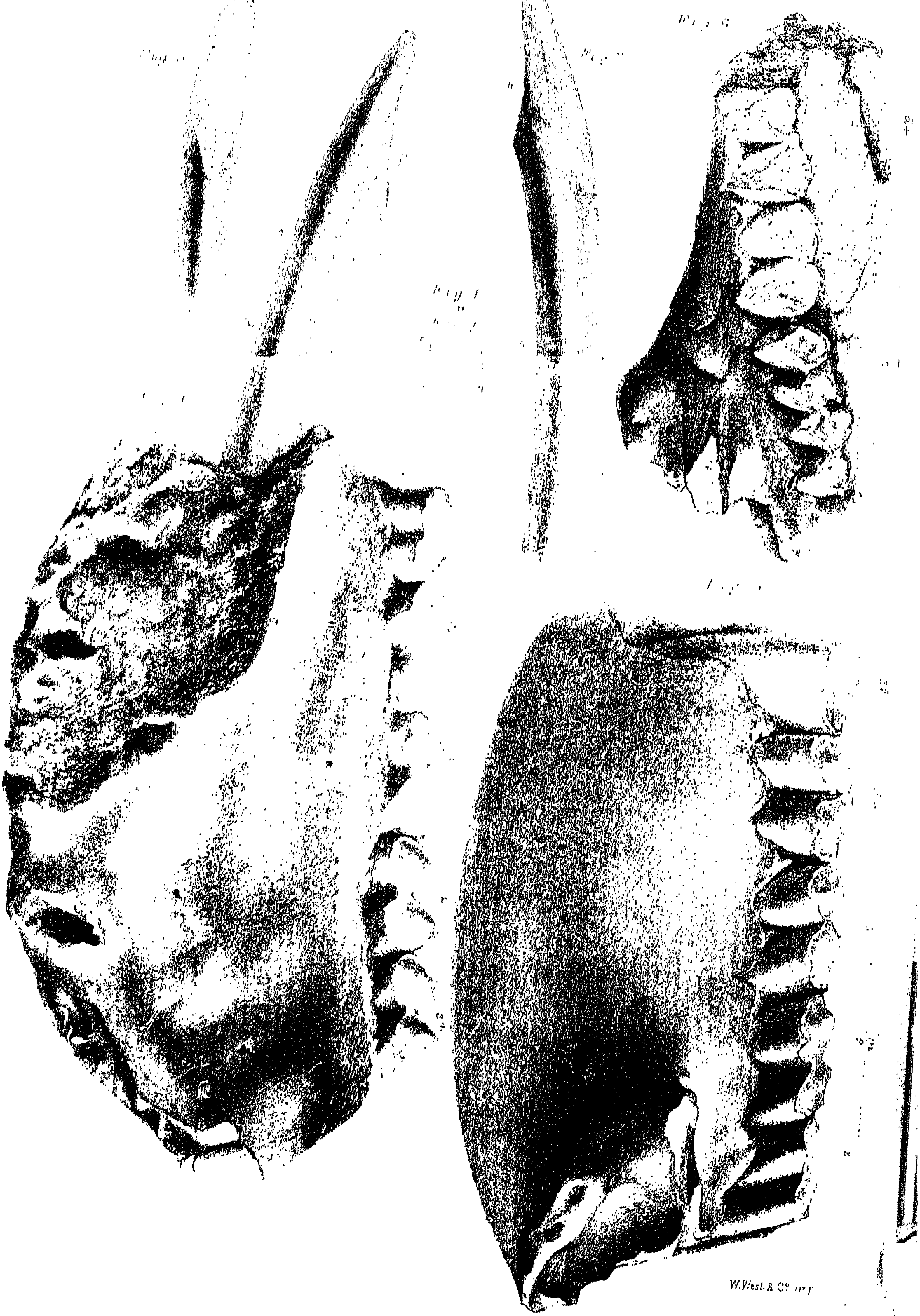
Fig. 1. Upper surface of fore part of mandible, *Phascolomys gigas*.
Fig. 2. Under surface of the same fossil.
Fig. 3. Back view, showing roots of incisors (i') and anterior molars (d_3) of the same fossil.
Fig. 4. Under surface of fore part of mandible, *Phascolomys vombatus*.

PLATE XL.

Fig. 1. Inner side view of the fore part of a right mandibular ramus and teeth, *Phasco-*

Fig. 2. Outer side view of incisor of the same fossil.
Fig. 3. Working-surface of the same incisor.
Fig. 4. Transverse section of the same incisor.
Fig. 5. Outer side view of the same fossil (without reversing).
Fig. 6. Upper view of a portion of the left mandibular ramus and last four molars of a smaller *Phascolomys gigas.*

All the figures are of the natural size: the symbols and letters of reference are explained in the text.



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XII. *On the Contact of Surfaces.* *By* WILLIAM SPOTTISWOODE, *M.A.*, *Treas. R.S.*

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IN a paper published in the Philosophical Transactions (1870, p. 289) I have considered the contact, at a point P, of two curves which are coplanar sections of two surfaces (U, V), and have examined somewhat in detail the case where one of the curves, viz. the section of V, is a conic. In the method there employed, the condition that the point P should be sextactic, involved the azimuth of the plane of section measured about an axis passing through P; and consequently, regarded as an equation in the azimuth, it showed that the point would be sextactic for certain definite sections. It does not, however, follow, if conics having six-pointic contact with the surface U be drawn in the planes so determined, that a single quadric surface can be made to pass through them all. In fact it will be shown in the sequel that when this is possible, the quadric in general degenerates into a pair of planes. The investigation therefore of the memoir above quoted was not directly concerned with the contact of surfaces, although it may be regarded as dealing with a problem intermediate to the contact of plane curves and that of surfaces.

In the present investigation I have considered a point P common to the two surfaces U and V, an axis drawn arbitrarily through P, and a plane of section passing through the axis and capable of revolution about it. Proceeding as in the former memoir, and forming the equations for contact of various degrees, and finally rendering them independent of the azimuth, we obtain the conditions for contact for all positions of the cutting plane about the axis. Such contact is called circumaxal; and in particular it is called uniaxal, biaxal, &c. according as it subsists for one, two, &c. axes. If it holds good for all axes through the point, it is called superficial contact.

It would at first sight seem that there should be a similar theory as to the number of axes about which contact must subsist in order that it may subsist about all axes, or be superficial. It is, indeed, found that if two-pointic contact be biaxal, or if three-pointic be triaxal, &c., the contact will be superficial. But this would prove too much, as it would give four conditions instead of two for two-pointic, six conditions instead of three for three-pointic, &c. superficial contact; and, in fact, it turns out that there are always in two-pointic contact one, in three-pointic two, &c. axes (viz. the tangents to the branches of the curve of contact through the point) about which the contact is circumaxal *per se*, so that the theory in one sense disappears. But as it at first had a semblance of existence, it may still be worth while to have laid its ghost.

At the conclusion of § 3 it is shown that the method of plane sections may, in the

cases possessing most interest and importance, be replaced by the more general method of curved sections.

In the concluding section a few general considerations are given relating to the determination of surfaces having superficial contact of various degrees with given surfaces; and at the same time it is indicated how very much the general theory is affected by the particular circumstances of each case. The question of a quadric having four-pointic superficial contact with a given surface is considered more in detail; and it is shown how in general such a quadric degenerates into the tangent plane taken twice. To this there is apparently an exceptional case, the condition for which is given and reduced to a comparatively simple form; but I must admit to having so left it, in the hope of giving a fuller discussion of it on a future occasion.

The subject of three-pointic superficial contact was considered by DUPIN, 'Développements de Géométrie,' p. 12; and, as I have learnt since the memoir was written, a general theorem connecting superficial contact and contact along various branches of the curve of intersection of two surfaces (substantially the same as that given in the text) was enunciated by M. MOUTARD*.

§ 1. *Preliminary Formulæ and Transformations.*

Let $U=0$, $V=0$ be the equations of the two surfaces whose contact is the subject of investigation. Let their degrees be m and n respectively; and let, as usual,

$$\left.\begin{array}{llll} \partial_x U=u, & \partial_y U=v, & \partial_z U=w, & \partial_t U=k, \\ \partial_x^2 U=u_1, & \partial_y^2 U=v_1, & \partial_z^2 U=w_1, & \partial_t^2 U=k_1, \\ \partial_y\partial_z U=u', & \partial_z\partial_x U=v', & & \partial_x\partial_y U=w', \\ \partial_x\partial_t U=l', & \partial_y\partial_t U=m', & & \partial_z\partial_t U=n'. \end{array}\right\} \quad \ldots \ldots \quad (1)$$

Also let $\overline{u}, \overline{v}, \ldots \overline{u}_1, \overline{v}_1, \ldots \overline{u}', \ldots \overline{l}', \ldots$ represent the corresponding differential coefficients of V.

Further, $\alpha, \beta, \gamma, \delta, \alpha', \beta', \gamma', \delta'$ being arbitrary quantities, let

$$\begin{aligned} \alpha x+\beta y+\gamma z+\delta t&=\varpi, \\ \alpha' x+\beta' y+\gamma' z+\delta' t&=\varpi', \\ \alpha'\varpi-\alpha\varpi'&=\mathrm{A}, \\ \beta'\varpi-\beta\varpi'&=\mathrm{B}, \\ \gamma'\varpi-\gamma\varpi'&=\mathrm{C}, \\ \delta'\varpi-\delta\varpi'&=\mathrm{D}. \end{aligned} \quad (2)$$

Also, forming the determinants in the usual order, let

$$a, b, c, f, g, h=\left\| \begin{array}{cccc} \alpha, & \beta, & \gamma, & \delta, \\ \alpha', & \beta', & \gamma', & \delta', \end{array} \right\| \quad \ldots \ldots \ldots \quad (3)$$

* Poncelet, 'Applications d'Analyse à la Géométrie,' 1864, tom. ii. p. 363.

viz. a, b, c, f, g, h are the six coordinates of the line of intersection of the planes ϖ, ϖ', or *the axis* as it may be termed; and $A=0$, $B=0$, $C=0$, $D=0$, $Ax+By+Cz+Dt=0$ represent five planes passing through the axis, the azimuth of the last plane about the axis being determined by the quantity $\varpi' : \varpi$.

This being so, the quantities $a, b, \ldots A, B, \ldots$ will be found to satisfy the following relations:—

$$\left.\begin{aligned} Bh-Cg+Da&=0,\\ Cf-Ah+Db&=0,\\ Ag-Bf+Dc&=0,\\ Aa+Bb+Cc&=0,\\ af+bg+ch&=0;\end{aligned}\right\} \quad \ldots \ldots \ldots \quad (4)$$

while for every point of the plane $Ax+By+Cz+Dt=0$ we shall have also

$$\left.\begin{aligned} bz-cy-ft&=A,\\ cx-az-gt&=B,\\ ay-bx-ht&=C,\\ fx+gy+hz&=D,\\ Ax+By+Cz+Dt&=0.\end{aligned}\right\} \quad \ldots \ldots \ldots \quad (4a)$$

Again, let

$$\left|\begin{matrix} \alpha, & \beta, & \gamma, & \delta, \\ \alpha', & \beta', & \gamma', & \delta', \\ u, & v, & w, & k, \\ \partial_x, & \partial_y, & \partial_z, & \partial_t \end{matrix}\right| V. \quad \ldots \ldots \ldots \quad (5)$$

Then if we write

$$x(\text{column } 1)+y(\text{column } 2)+z(\text{column } 3)+t(\text{column } 4)$$

for each of the columns in succession of the expression for $\square V$, it will be found that the following transformation may be effected, viz.

$$x\square V,\ y\square V,\ z\square V,\ t\square V=\left\|\begin{matrix} A, & B, & C, & D, \\ u, & v, & w, & k, \\ \partial_x, & \partial_y, & \partial_z, & \partial_t \end{matrix}\right\| V. \quad \ldots \ldots \quad (6)$$

Again, let

$$\delta_1, \delta_2, \delta_3, \delta_4, \delta_5, \delta_6=\left\|\begin{matrix} u, & v, & w, & k, \\ \partial_x, & \partial_y, & \partial_z, & \partial_t \end{matrix}\right\|. \quad \ldots \ldots \ldots \quad (7)$$

then it will be found that

$$\left.\begin{aligned}\square V&=(a\delta_4+b\delta_5+c\delta_6+f\delta_1+g\delta_2+h\delta_3)V,\\ x\square V&=(B\delta_6-C\delta_5+D\delta_1)V=(\varpi'\square_1-\varpi\square'_1)V,\\ y\square V&=(C\delta_4-A\delta_6+D\delta_2)V=(\varpi'\square_2-\varpi\square'_2)V,\\ z\square V&=(A\delta_5-B\delta_4+D\delta_3)V=(\varpi'\square_3-\varpi\square'_3)V,\\ t\square V&=(A\delta_1+B\delta_2+C\delta_3)V=(\varpi'\square_4-\varpi\square'_4)V,\end{aligned}\right\} \quad \dots\dots \quad (8)$$

where

$$\left.\begin{aligned}\square_1&=\beta\delta_6-\gamma\delta_5+\delta\delta_1, & \square'_1&=\beta'\delta_6-\gamma'\delta_5+\delta'\delta_1,\\ \square_2&=\gamma\delta_4-\alpha\delta_6+\delta\delta_2, & \square'_2&=\gamma'\delta_4-\alpha'\delta_6+\delta'\delta_2,\\ \square_3&=\alpha\delta_5-\beta\delta_4+\delta\delta_3, & \square'_3&=\alpha'\delta_5-\beta'\delta_4+\delta'\delta_3,\\ \square_4&=\alpha\delta_1+\beta\delta_2+\gamma\delta_3, & \square'_4&=\alpha'\delta_1+\beta'\delta_2+\gamma'\delta_3.\end{aligned}\right\} \quad (9)$$

Lastly, the operators δ_1, δ_2, .. are subject to the following identical relations, viz.:—

$$\left.\begin{aligned}v\delta_6-w\delta_5+k\delta_1&=0,\\ w\delta_4-u\delta_6+k\delta_2&=0,\\ u\delta_5-v\delta_4+k\delta_3&=0,\\ u\delta_1+v\delta_2+w\delta_3&=0,\end{aligned}\right\} \quad \dots\dots\dots \quad (10)$$

by means of which we may always eliminate one of the three operators entering into each of the expressions (8). In fact, the following values would express the result of such an elimination:—

$$\left.\begin{aligned}k(B\delta_6-C\delta_5+D\delta_1)&=(Bk-Dv)\delta_6-(Ck-Dw)\delta_5,\\ k(C\delta_4-A\delta_6+D\delta_2)&=(Ck-Dw)\delta_4-(Ak-Du)\delta_6,\\ k(A\delta_5-B\delta_4+D\delta_3)&=(Ak-Du)\delta_5-(Bk-Dv)\delta_4;\end{aligned}\right\} \quad \dots\dots \quad (11)$$

so that in the case where $\square V=0$, we should obtain

$$\delta_1V:\delta_2V:\delta_3V:\delta_4V:\delta_5V:\delta_6V=\left\Vert\begin{matrix}A, & B, & C, & D,\\ u, & v, & w, & k.\end{matrix}\right\Vert \quad \dots \quad (12)$$

There is one other mode of transformation which, on account of its utility, may properly find a place here. If U_0, U_1, be the same linear functions of α, β, γ, δ, and α', β', γ', δ', respectively, say

$$\left.\begin{aligned}U_0&=(\alpha, & \beta, & \gamma, & \delta),\\ U_1&=(\alpha', & \beta', & \gamma', & \delta'),\end{aligned}\right\} \quad (13)$$

then it will be found that

$$\left.\begin{aligned}(U_0, U_1)(\alpha', -\alpha)&=(\ \ .\ \ \ c,\ -b,\ f),\\ (U_0, U_1)(\beta', -\beta)&=(-c,\ \ .\ \ \ a,\ g),\\ (U_0, U_1)(\gamma', -\gamma)&=(\ b,\ -a,\ \ .\ \ \ h),\\ (U_0, U_1)(\delta', -\delta)&=(\ f,\ \ g,\ \ h,\ \ \ .\ )\end{aligned}\right\} \quad (14)$$

Similarly, if U_0, U_1, U_2 be the same functions, the first quadratic in $\alpha, \beta, \gamma, \delta$; the second lineo-linear in $\alpha, \beta, \gamma, \delta$; $\alpha', \beta', \gamma', \delta'$; the third quadratic in $\alpha', \beta', \gamma', \delta'$, say,

$$\left.\begin{aligned} U_0&=(\alpha, \beta, \gamma, \delta)^2, \\ U_1&=(\alpha, \beta, \gamma, \delta)(\alpha', \beta', \gamma', \delta'), \\ U_2&=(\alpha', \beta', \gamma', \delta'), \end{aligned}\right\} \quad \ldots \ldots \ldots \quad (15)$$

then it will be found that

$$\left.\begin{aligned} (U_0, U_1, U_2), (\alpha', -\alpha)^2&=(\ .\ c, -b, f)^2, \\ (U_0, U_1, U_2), (\beta', -\beta)^2&=(-c,\ .\ a, g)^2, \\ &\vdots \\ (U_0, U_1, U_2)(\beta', -\beta)(\gamma', -\gamma)&=(-c,\ .\ a, g)(b, -a,\ .\ h), \\ &\vdots \\ (U_0, U_1, U_2)(\alpha', -\alpha)(\delta', -\delta)&=(\ .\ c, -b, f)(f, g, h, .). \\ &\vdots \end{aligned}\right\} \quad \ldots \quad (16)$$

And a similar process is also obviously applicable to functions of higher degrees.

§ 2. *Conditions of Contact.*

In the memoir "On the Contact of Conics with Surfaces," above quoted, it was shown that the conditions for a 1, 2, .. pointic contact at a point P of the curves of section of the surfaces U, V, made by a plane $Ax+By+Cz+Dt=0$, may be expressed as follows:

$$V=0, \quad \square V=0, \quad \square^2 V=0\ldots, \quad \ldots \ldots \quad (17)$$

The cutting plane, say the plane (A, B, C, D), was supposed to pass through the point (x, y, z, t), say the point P, to be capable of revolving about the axis whose six coordinates are (a, b, c, f, g, h), and to have an azimuth which, measured about the axis, is determined by the quantity $\varpi' : \varpi$.

The equations (17) may be supposed to be expressed in any of the forms to which they were reduced in § 1. Taking, for instance, the form (8), and dropping for the present the suffixes, so that $\square$, $\square'$ shall be understood to represent any pair of the operators $\square_1, \ldots \square'_1, \ldots$, the equations (17) may be written thus:

$$V=0, \ (\varpi'\square-\varpi\square')V=0, \quad (\varpi'\square-\varpi\square')^2V=0\ldots, \quad \ldots \ldots \quad (18)$$

In the expansion of these expressions there will occur combinations such as $\delta_i\delta_jV$, where i and j represent any of the numbers 1, 2, 3, 4; and when i and j are different, the compound operation $\delta_j\delta_i$ is not in general the same as $\delta_i\delta_j$. But in the case where $\delta_iV=0$, $\delta_jV=0$, it will be found on actual trial of the special forms that $\delta_j\delta_iV=\delta_i\delta_jV$. The same thing may be also proved by the following considerations, which are applicable to all the forms of δ_i and δ_j. In the first place δ_i is symmetrical, except as regards algebraical sign, in respect of the first differential coefficients of U and V; so that if δ_i be the expression obtained by replacing the differential coefficients of U by

those of $-V$ in δ_i, we may write $\delta_i V=\bar{\delta}_i U$. Secondly, the result of any combined operation such as $\delta_j\delta_i U$ consists of two parts, say $\delta'_j\delta_i V$ (or $\delta'_j\delta'_i V$), where the accented operators affect V only, and $\delta''_j\delta_i V=\delta''_j\bar{\delta}_i U$ (or $\delta''_j\bar{\delta}''_i U$), where the doubly accented operators affect U only. But the conditions $\delta_i V=0$, $\delta_j V=0$ give, as is well known, $\partial_x V=\theta u$, $\partial_y V=\theta v$,.., where θ is indeterminate; so that if, after the operations $\delta''_j\bar{\delta}''_i$ have been performed on U, we replace $\partial_x V$ by θu, $\partial_y V$ by θv, we shall have an expression identical with that obtained by evaluating $\delta''_i\bar{\delta}''_j U$. In other words,

$$\text{when } \delta_i V=0, \quad \delta_j V=0, \text{ then } \delta_j\delta_i V=\delta_i\delta_j V. \qquad (19)$$

Similarly, if, in addition to $\delta_i V=0$, $\delta_j V=0$, we have

$$\delta_i^2 V=0,\ \delta_j\delta_i V=0,\ \delta_j^2 V=0, \qquad (20)$$

then

$$\left.\begin{array}{ll} \because\ \delta_i^2 V=0, \quad \delta_j\delta_i V=0, & \therefore\ \delta_i\delta_j\delta_i V=\delta_j\delta_i^2 V, \\ \because\ \delta_j^2 V=0, \quad \delta_i\delta_j V=0, & \therefore\ \delta_j\delta_i\delta_j V=\delta_i\delta_j^2 V, \\ \because\ \delta_i\delta_j V=\delta_j\delta_i V=0, & \therefore\ \delta_i^2\delta_j V=\delta_j\delta_i^2 V. \end{array}\right\} \qquad (21)$$

The equations (18) may be regarded as equations involving an unknown quantity $\varpi':\varpi$, which determines the section along which there is a contact of a given degree. Thus, in order that the surfaces may have a p-pointic contact at the point P along some section through the axis, we must have

$$(\varpi'\Box-\varpi\Box')^{p-1}V=0. \qquad (22)$$

But, inasmuch as whenever there is a p-pointic contact along any section there must also be a $p-1, p-2,$.. pointic contact, it follows that, in addition to the condition above written, we must also have

$$(\varpi'\Box-\varpi\Box')^{p-2}V=0, \quad (\varpi'\Box-\varpi\Box')^{p-3}V=0\ ..; \qquad (23)$$

and the conditions for the existence of a p-pointic contact at the point P along some section through the axis will be expressed by eliminating $\varpi':\varpi$ from the equations (22), (23), taken two and two together.

Thus the condition for a three-pointic would be

$$(\Box'V)^2\Box^2V-\Box'V\Box V(\Box\Box'+\Box'\Box)V+(\Box V)^2\Box'^2V=0, \qquad (24)$$

or

$$(\Box^2V,\ (\Box\Box'+\Box'\Box)V,\ \Box'^2V)(\Box'V,\ -\Box V)^2=0. \qquad (25)$$

Similarly, for a four-pointic contact we should have, in addition to (25), the following:

$$(\Box^3V,\ (\Box'\Box^2+\Box\Box'\Box+\Box^2\Box')V,\ (\Box'^2\Box+\Box'\Box\Box'+\Box\Box'^2)V,\ \Box'^3V)(\Box'V,\ -\Box V)^3=0, \quad (2$$

and so on, for higher degrees, the azimuth of the plane section being always determined by the value of $\Box'V:\Box V$ at the point P. And it may be observed that, under the conditions supposed, there will in general be only one plane section along which the contact will subsist.

If the surfaces touch at the point P, the equation $(\varpi'\square-\varpi\square')V=0$ is satisfied identically, and there will in general be two directions, determined by the equation

$$(\varpi'\square-\varpi\square')^2V=0, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (27)$$

along which there will be three-pointic contact, as will be further noticed in the next section. The condition for a four-pointic contact will then be obtained by eliminating $\varpi':\varpi$ from the equations (27) and (26). These considerations may readily be extended to higher degrees.

It will perhaps be worth while before proceeding further to evaluate the expression (24); viz. the condition to be fulfilled in order that when two surfaces meet at a point P but do not touch, the curves of section made by some plane passing through a given axis through P shall have three-pointic contact. With a view to this, let us take the following form for $\square$, viz.

$$\square=\alpha\delta_1+\beta\delta_2+\gamma\delta_3, \quad \square'=\alpha'\delta_1+\beta'\delta_2+\gamma'\delta_3. \quad . \quad . \quad . \quad . \quad . \quad . \quad (28)$$

Then the expression to be developed will be

$$\begin{aligned}&(\alpha'\delta_1V+..)^2(\alpha^2\delta_1^2+\beta^2\delta_2^2+..+2\beta\gamma(\delta_1\delta_2+\delta_2\delta_1)+..)V\\ &-(\alpha\delta_1V+..)(\alpha'\delta_1V+..)(2\alpha\alpha'\delta_1^2+2\beta\beta'\delta_2^2+..(\beta\gamma'+\beta'\gamma)(\delta_1\delta_2+\delta_2\delta_1)+..)V\\ &+(\alpha\delta_1V+..)^2(\alpha'^2\delta_1^2+\beta'^2\delta_2^2+..+2\beta'\gamma'(\delta_1\delta_2+\delta_2\delta_1)+..)V.\end{aligned}$$

In this it will be found that the coefficients of $\alpha'^2\alpha^2$, $\beta'^2\beta^2$, .. vanish, and that the coefficients of $\alpha^2\beta'^2$, $-2\alpha\alpha'\beta\beta'$, $\alpha'^2\beta^2$ are all the same, viz.

$$(\delta_1V)^2\delta_2^2V-\delta_1V\delta_2V(\delta_1\delta_2+\delta_2\delta_1)V+(\delta_2V)^2\delta_1^2V.$$

Hence the whole expression may be reduced to the form

$$\{a^2(\delta_2V\delta_3-\delta_3V\delta_2)^2+..+2bc(\delta_3V\delta_1-\delta_1V\delta_3)(\delta_1V\delta_2-\delta_2V\delta_1)+..\}V, \quad . \quad . \quad (29)$$

it being understood that the operations δ_1, δ_2, δ_3 do not affect the quantities δ_1V, δ_2V, δ_3V so far as they appear explicitly in the above expression. In order to calculate the coefficients of the powers and products of a, b, c, we have

$$\left.\begin{aligned}&\delta_1V=v\bar{w}-w\bar{v}, \quad \delta_2V=w\bar{u}-u\bar{w}, \quad \delta_3V=u\bar{v}-v\bar{u},\\ &\delta_1u=vv'-ww', \quad \delta_2u=wu_1-uv', \quad \delta_3u=uw'-vu_1,\\ &\delta_1v=vu'-wv_1, \quad \delta_2v=ww'-uu', \quad \delta_3v=uv_1-vw',\\ &\delta_1w=vw_1-wu', \quad \delta_2w=wv'-uw_1, \quad \delta_3w=uu'-vv',\\ &\delta_1^2V=v^2\bar{w}_1-2vw\bar{u}'+w^2\bar{v}_1 \qquad +\bar{w}(vu'-wv_1)-\bar{v}(vw_1-wu'),\\ &\delta_1\delta^2V=uw\bar{u}'+vw\bar{v}'-w^2\bar{w}'-uv\bar{w}_1+\bar{u}(vw_1-wu')-\bar{w}(vv'-ww'),\\ &\delta_2\delta_1V=uw\bar{u}'+vw\bar{v}'-w^2\bar{w}'-uv\bar{w}_1+\bar{w}(ww'-uu')-\bar{v}(wv'-uw_1),\\ &\delta_2^2V=w^2\bar{u}_1-2wu\bar{v}'+u^2\bar{w}_1 \qquad +\bar{u}(wv'-uw_1)-\bar{w}(wu_1-uv'),\end{aligned}\right\} \quad . \quad . \quad (30)$$

each of which consists of two parts; viz. the first involves the second differential coeffi-

cients of V, the second the first differential coefficients of V. This being so, the first part of the coefficient of c^2, viz. $(\delta_1 V\delta_2-\delta_2 V\delta_1)^2 V$, will be

$$\begin{aligned}
&=(w\bar{u}-u\bar{w})^2(v^2\bar{w}_1-2vw\bar{u}'+w^2\bar{v}_1)\\
&\quad-2(w\bar{u}-u\bar{w})(v\bar{w}-w\bar{v})(wu\bar{u}'+vw\bar{v}'-w^2\bar{w}'-uv\bar{w}_1)\\
&\quad+(v\bar{w}-w\bar{v})^2(w^2\bar{u}_1-2wu\bar{v}'+u^2\bar{w}_1)\\
&=w^2\{(v\bar{w}-w\bar{v})^2\bar{u}_1+(w\bar{u}-u\bar{w})^2\bar{v}_1+(u\bar{v}-v\bar{u})^2w_1\\
&\qquad+2(w\bar{u}-u\bar{w})(u\bar{v}-v\bar{u})u'\\
&\qquad+2(u\bar{v}-v\bar{u})(v\bar{w}-w\bar{v})v'\\
&\qquad+2(v\bar{w}-w\bar{v})(w\bar{u}-u\bar{w})w'\}
\end{aligned}$$

$$\left|\begin{matrix} {}_1, & \bar{w}', & \bar{v}', & \bar{u}, & u, \\ {}', & \bar{v}_1, & \bar{u}', & \bar{v}, & v, \\ {}', & \bar{u}', & \bar{w}_1, & \bar{w}, & w, \\ \bar{u}, & \bar{v}, & \bar{w}, & . & ., \\ u, & v, & w, & . & ., \end{matrix}\right| =\frac{w^2t^2}{(m-1)^2}\left|\begin{matrix} \bar{u}_1, & \bar{w}', & \bar{v}', & \bar{l}', & u, \\ \bar{w}', & \bar{v}_1, & \bar{u}', & \bar{m}', & v, \\ \bar{v}', & \bar{u}', & \bar{w}_1, & \bar{u}', & w, \\ \bar{l}', & \bar{m}', & \bar{u}', & \bar{k}_1, & k, \\ u, & v, & w, & k, & . \end{matrix}\right| =\frac{w^2t^2}{(m-1)^2}\bar{\Omega} \text{ suppose}$$

and the second part of the same expression

$$\begin{aligned}
&=(w\bar{u}-u\bar{w})^2\{-w\bar{w}v_1+(v\bar{w}+w\bar{v})u'-v\bar{w}w_1\}\\
&\quad-(w\bar{u}-w\bar{w})(v\bar{w}-w\bar{v})\{-(w\bar{u}+u\bar{w})u'-(v\bar{w}+w\bar{v})v'+2w\bar{w}w'+(u\bar{v}+v\bar{u})\bar{w}_1\}\\
&\quad+(v\bar{w}-w\bar{v})^2\{-u\bar{u}w_1+(w\bar{u}+u\bar{w})v'-w\bar{w}u_1\}\\
&\qquad=-w\bar{w}\{(v\bar{w}-w\bar{v})^2u_1+(w\bar{u}-u\bar{w})^2v_1+(u\bar{v}-v\bar{u})^2w_1\\
&\qquad\qquad+2(w\bar{u}-u\bar{w})(u\bar{v}-v\bar{u})u'\\
&\qquad\qquad+2(u\bar{v}-v\bar{u})(v\bar{w}-w\bar{v})v'\\
&\qquad\qquad+2(v\bar{w}-w\bar{v})(w\bar{u}-uw)w'\}
\end{aligned}$$

$$\cdot\frac{wwt^2}{(u-1)^2}\begin{matrix} u_1, & w', & v', & \bar{l}, & u \\ w', & v_1, & u', & m', & \bar{v} \\ v', & u', & w_1, & u', & \bar{w} \\ l', & m', & u', & k_1, & k \\ \bar{u}, & \bar{v}, & \bar{w}, & \bar{k}, & . \end{matrix} \qquad \cdot\frac{w\bar{w}t^2}{(u-1)^2}\,\Omega \text{ suppose.}$$

Hence the whole expression (29)

$$=(au+bv+cw)t^2\left\{(au+bv+cw)\frac{\bar{\Omega}}{(m-1)^2}-(a\bar{u}+b\bar{v}+c\bar{w})\frac{\Omega}{(u-1)^2}\right\}.$$

Hence the condition for a three-pointic contact in some plane about a given axis will be

$$(au+bv+cw)\frac{\bar{\Omega}}{(m-1)^2}-(a\bar{u}+b\bar{v}+c\bar{w})\frac{\Omega}{(u-1)^2}=0. \quad . \quad . \quad . \quad . \quad . \quad (31)$$

This may be regarded as a condition to be fulfilled either by a, b, c, the direction cosines of the axis, or by x, y, z, t, the coordinates of the point. Taking the first view, $au+bv+cw=0$ is the condition that the axis shall lie in the tangent plane of U, and $a\bar{u}+b\bar{v}+c\bar{w}=0$ the condition that it shall lie in the tangent plane of V; hence (31) expresses the condition that the axis shall lie in the intersection of these planes.

On the other hand, regarding a, b, c as given, the equation (31) will represent a surface whose intersections with U and V will determine the points of three-pointic contact about a given axis. The degree of this surface is $3(m+n-3)$; and the number of points will therefore be $3mn(m+n-3)$.

Lastly, the equation (31) becomes independent of a, b, c if

$$\bar{\Omega}=0, \quad \Omega=0, \quad \ldots \ldots \ldots \ldots \quad (32)$$

which will consequently express the conditions that a three-pointic contact may subsist in some plane about any axis. The degrees of these equations are $2(n-1)+3(m-2)$, and $2(m-1)+3(n-2)$ respectively. Points for which such contact will subsist for any axis do not in general exist when U and V do not touch; but the condition for their existence will be found by eliminating x, y, z, t from the equations $U=0$, $V=0$, $\Omega=0$, $\bar{\Omega}=0$.

§ 3. *Modes of Contact.*

Hitherto we have considered only the contact of the curves of section of the surfaces U, V made by definite planes passing through an axis. If, however, in the equations (18), which express the conditions for the contact of these curves, we equate to zero the coefficients of the various powers of the quantity $\varpi':\varpi$, which determines the azimuth, we shall obtain a new series of conditions. And the fulfilment of these conditions will ensure the subsistence of contact, of the degree under consideration, independently of the azimuth of the cutting plane; or, in other words, for all plane sections round the point P whose planes of section pass through the axis, such contact may be called *circumaxal*; and, in particular, contact which holds good in this manner for a single axis might be termed *uniaxal contact*; that which holds good similarly for two axes might be termed *biaxal contact*; and so on for a greater number of axes. But before entering into this question, it will be as well to establish a theorem relating to the number of sections necessary to ensure uniaxal contact.

Returning to equations (18); the second, viz $(\varpi'\Box-\varpi\Box')V=0$, expresses the condition for two-pointic contact. Suppose that this holds good for more than one value of $\varpi':\varpi$, say, $\varpi'_1:\varpi_1$ and $\varpi'_2:\varpi_2$. Then, writing down the equation for each of these values, we may eliminate the coefficients and obtain the resultant,

$$\varpi_2\varpi'_2-\varpi_2\varpi'_1=0. \quad \ldots \ldots \ldots \ldots \quad (33)$$

But as $\varpi'_1:\varpi_1$ and $\varpi'_2:\varpi_2$ are by hypothesis different, the above equation cannot be satisfied, and consequently the coefficients of ϖ' and ϖ in the equation under consideration must separately vanish. But the evanescence of these coefficients expresses the con-

ditions for universal two-pointic contact. Hence if a two-pointic contact subsists for two positions of the cutting plane about an axis, it will subsist for all positions about that axis. It will be shown in the sequel, as is well known from other considerations, that under these circumstances the contact will hold good for all axes through the point P. A similar result follows in the case of three-pointic contact. If the third equation of (18) holds good for three values of $\varpi' : \varpi_1$, say $\varpi'_1 : \varpi_1$; $\varpi'_2 : \varpi_2$; $\varpi'_3 : \varpi_3$, then writing down the equation for the three values successively, we shall be able to eliminate the three coefficients of the powers of $\varpi' : \varpi$ and obtain the resultant,

$$= -(\varpi_2\varpi'_3 - \varpi'_2\varpi_3)(\varpi_3\varpi'_1 - \varpi_1\varpi'_3)(\varpi_1\varpi'_2 - \varpi_2\varpi'_1) = 0, \quad . \quad . \quad . \quad . \quad . \quad (34)$$

which cannot be satisfied, since by hypothesis the three values of $\varpi' : \varpi$ are all different. Hence the coefficients of the equation in question must separately vanish. In other words, if a three-pointic contact subsist for three positions of the cutting plane about an axis, it will subsist for all positions about that axis.

The same law may obviously be extended to contacts of higher degrees.

The axis may be drawn, as before stated, in any direction through the point P; it may therefore be made to coincide with a tangent to the curve of intersection of U and V at the point. But in that case it is obvious that two-pointic contact would subsist for two positions (in fact for all positions) of the cutting plane without involving the conditions for the ordinary contact of the two surfaces (viz. $\delta_1 V=0$, $\delta_2 V=0$, $\delta_3 V=0$) as a consequence. It is perhaps desirable to show that the formulæ here employed take cognizance of this circumstance, as well as of the corresponding circumstances in the cases of contact of higher degrees.

Suppose, then, that two-pointic contact subsists for two positions of the cutting plane about the axis, say for the two planes (A, B, C, D), (A_1, B_1, C_1, D_1); then, adopting the last form of the group (8), we have the two equations

$$\left.\begin{aligned} A\delta_1 V + B\delta_2 V + C\delta_3 V = 0, \\ A_1\delta_1 V + B_1\delta_2 V + C_1\delta_3 V = 0. \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (35)$$

Adding to these the two identical equations,

$$u\delta_1 U + v\delta_2 V + w\delta_3 V = 0,$$
$$\bar{u}\delta_1 U + \bar{v}\delta_2 V + \bar{w}\delta_3 V = 0,$$

and eliminating $\delta_1 V$, $\delta_2 V$, $\delta_3 V$, we obtain the resultants

$$\left\| \begin{matrix} & \bar{u}, & A, & A_1, \\ v, & \bar{v}, & B, & B_1, \\ w, & \bar{w}, & C, & C_1, \end{matrix} \right\| = 0. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (36)$$

And if we regard these equations as determining a particular direction for the axis, they express the condition that it must coincide with the tangent line to the curve of intersection of U and V at the point P; so that in this particular case the equations (35) do not involve $\delta_1 V=0, \ldots$ as a consequence.

Again, in the case of three-pointic contact, we may take the following form, viz.

$$A^2\delta_1^2 V+B^2\delta_2^2 V+\ldots+2BC\delta_2\delta_3 V+\ldots=0. \qquad (37)$$

Then, since the operation $u\delta_1+v\delta_2+w\delta_3$ vanishes identically, we obtain, by operating with it upon u, v, w respectively, and then eliminating u, v, w, the following resultant:—

$$\left|\begin{matrix} \delta_1^2 V, & \delta_2\delta_1 V, & \delta_3\delta_1 V, \\ \delta_1\delta_2 V, & \delta_2^2 V, & \delta_3\delta_2 V, \\ \delta_1\delta_3 V, & \delta_2\delta_3 V, & \delta_3^2 V \end{matrix}\right|=0. \qquad (38)$$

But this is the condition that (37) may be resolved into linear factors. Supposing it so resolved into the product $(AP+\ldots)(AP_1+\ldots)$, then one of these factors must vanish in virtue of (37). If, then, the contact subsists for three positions of the cutting plane, we may write

$$AP+\ldots=0, \quad A_1P+\ldots=0, \quad A_2P+\ldots=0; \qquad (39)$$

to which we may add, in virtue of the identical equations,

$$u^2\delta_1^2 V+v^2\delta_2^2 V+\ldots+2vw\delta_2\delta_3 V+\ldots=(uP+\ldots)(uP_1+\ldots)=0,$$
$$\bar{u}^2\delta_1^2 V+\bar{v}^2\delta_2^2 V+\ldots+2\bar{v}\bar{w}\delta_2\delta_3 V+\ldots=(\bar{u}P+\ldots)(\bar{u}P_1+\ldots)=0,$$

the following,

$$uP+\ldots=0, \quad \bar{u}P+\ldots=0; \qquad (40)$$

whence, eliminating $P, \ldots$, we obtain

$$\left\|\begin{matrix} u, & \bar{u}, & A, & A_1, & A_2, \\ v, & \bar{v}, & B, & B_1, & B_2, \\ w, & \bar{w}, & C, & C_1, & C_2 \end{matrix}\right\|=0, \qquad (41)$$

showing that if the planes all intersect in a tangent to the curve of intersection, the conditions $\delta_1^2 V=0$, $\delta_2^2 V=0, \ldots$ are not of necessity fulfilled.

It is perhaps unnecessary to pursue this part of the subject further.

Returning from this digression to the equations (18), it may be observed that if there be two-pointic circumaxal contact about the point P, *i. e.* when $\Box V=0$, $\Box' V=0$, the equation $(\varpi'\Box-\varpi\Box')^2 V=0$ will be satisfied by two values of $\varpi':\varpi$; in other words, the curve of intersection of U and V will have a double point at P, and along each of the branches the contact will be three-pointic. Similarly, if there be three-pointic circumaxal contact about the point P, *i. e.* when in addition to the former ($\Box V=0$, $\Box' V=0$), we have $\Box^2 V=0$, $(\Box'\Box+\Box\Box')V=0$, $\Box'^2 V=0$, then the equation $(\varpi'\Box-\varpi\Box')^3 V=0$ will be satisfied by three values of $\varpi':\varpi$; that is, the curve of intersection will have a

triple point at P, and along each of the branches the contact will be four-pointic. This may be extended generally; but there will be occasion to return to the question hereafter*.

It having been proved that if p-pointic contact subsist for p plane sections about an axis it will subsist for all plane sections about that axis, the question naturally suggests itself whether there be not a corresponding theory as to the number of axes about which there must be circumaxal contact in order that it may subsist for all axes. In uniaxal contact it is supposed that from the point P at which the surfaces meet a series of curves are drawn (on both surfaces) lying in planes passing through the axis, and that contact of the degree under consideration subsists between every curve on U and the corresponding curve on V. If the circumaxal contact be multiaxal, we are supposed to take other axes through P, and draw other series of curves in planes passing through these axes respectively; and the question is, whether it be necessary that the contact shall subsist for a definite number of these series of curves, in order that it may subsist for all such series. In the latter case we shall call the contact *superficial*; commencing with two-pointic contact, and taking the form $A\delta_1+B\delta_2+C\delta_3$ for $\square$, we obtain, on equating to zero the coefficients of ϖ', ϖ respectively,

$$\left.\begin{aligned}\alpha\delta_1V+\beta\delta_2V+\gamma\delta_3V=0,\\ \alpha'\delta_1V+\beta'\delta_2V+\gamma'\delta_3V=0;\end{aligned}\right\} \quad \ldots \ldots \ldots \quad (42)$$

and applying to these the transformation (14), we deduce the following forms,

$$(b\delta_3-c\delta_2)V=0, \quad (c\delta_1-a\delta_2)V=0, \quad (a\delta_2-b\delta_1)V=0,$$

or

$$\delta_1V:\delta_2V:\delta_3V=a:b:c. \quad \ldots \ldots \ldots \quad (43)$$

If this contact holds good for a second axis (say a_1, b_1, c_1), we shall have also

$$\delta_1V:\delta_2V:\delta_3V=a_1:b_1:c_1. \quad \ldots \ldots \ldots \quad (44)$$

But since the two axes by hypothesis do not coincide, (43) and (44) cannot both be satisfied except on the conditions

$$\delta_1V=0, \quad \delta_2V=0, \quad \delta_3V=0. \quad \ldots \ldots \ldots \quad (45)$$

These conditions are in reality only two in number, in consequence of the identical relation $u\delta_1+v\delta_2+w\delta_3=0$. This shows that if two-pointic contact be biaxal it will be superficial. But inasmuch as the directions of these axes are arbitrary, we may take for one of them the tangent to the curve of intersection of U and V through P; hence, setting this axis aside, and reckoning only arbitrary axes, we may state that if two-pointic contact be uniaxal it will be superficial. This, of course, is merely the ordinary property of common contact.

At the risk of being tedious on so simple a question, I venture to point out that a result substantially the same may be deduced by a geometrical consideration from the equation $(A\delta_1+B\delta_2+C\delta_3)V=0$, without the intervention of the suppositions (45). Take

* Since writing the above I have found that a similar theorem was enunciated by M. MOUTARD. PONCELET, 'Application d'Analyse à la Géométrie,' 1864, tom. ii. p. 363.

two axes passing through P (say PQ, PQ_1), and a pair of planes passing through each (say PQQ_1, PQQ_2, and PQ_1Q, PQ_1Q_2); then, if two-pointic contact subsist for each pair of planes, the contact will be biaxal, as was shown at the commencement of the present section. We shall now have three planes in all, PQ_1Q_2, PQ_2Q, PQQ_1 (say the planes A, B, C; A_1, B_1, C_1; A_2, B_2, C_2), forming a solid angle; and in virtue of the equation with which we started, we shall have

$$\left.\begin{aligned} A\,\delta_1V+B\,\delta_2V+C\,\delta_3V&=0,\\ A_1\delta_1V+B_1\delta_2V+C_1\delta_3V&=0,\\ A_2\delta_1V+B_2\delta_2V+C_2\delta_3V&=0. \end{aligned}\right. \qquad (46)$$

But as these planes by hypothesis do not pass through one and the same straight line, the determinant of these equations cannot vanish. Hence the system (46) can hold good only on the conditions $\delta_1V=0$, $\delta_2V=0$, $\delta_3V=0$. But we may take, as before, the tangent to the curve of intersection at P as one of the axes PQ, PQ_1. Hence we come to the same conclusion as before.

Passing to the case of three-pointic contact (and supposing that two-pointic superficial contact subsists at the point P), and equating to zero the coefficients of the powers of $\varpi':\varpi$ in the equation $(\varpi'\Box-\varpi\Box')^3V=0$, and adopting the same form as before, we shall obtain

$$\left.\begin{aligned} \alpha^2\,\delta_1^2V+\beta^2\,\delta_2^2V+\,..\,+2\beta\gamma\delta_2\delta_3V+\,..\,&=0,\\ \alpha\alpha'\delta_1^2V+\beta\beta'\delta_2^2V+\,..\,+(\beta\gamma'+\beta'\gamma)\delta_2\delta_3V+\,..\,&=0,\\ \alpha'^2\,\delta_1^2V+\beta'^2\,\delta_2^2V+\,..\,+2\beta'\gamma'\delta_2\delta_3V+\,..\,&=0, \end{aligned}\right\} \quad . \; . \; . \; . \; . \quad (47)$$

which, by means of the transformation (16), may be reduced to the following forms:—

$$\left.\begin{aligned} (c\delta_2-b\delta_3)^2V=0,\quad (a\delta_3-c\delta_1)^2V=0,\quad (b\delta_1-a\delta_2)^2V=0,\\ (a\delta_3-c\delta_1)(b\delta_1-a\delta_2)V=0,\\ (b\delta_1-a\delta_2)(c\delta_2-b\delta_3)V=0,\\ (c\delta_2-b\delta_3)(a\delta_3-c\delta_1)V=0, \end{aligned}\right. \qquad (48)$$

whereof three only are independent.

And if the contact be triaxal, we should have (taking the first of these forms)

$$\left.\begin{aligned} c^2\delta_2^2V-2b\,c\,\delta_2\delta_3V+b^2\delta_3^2V&=0,\\ c_1^2\delta_2^2V-2b_1c_1\delta_2\delta_3V+b_1^2\delta_3^2V&=0,\\ c_2^2\delta_2^2V-2b_2c_2\delta_2\delta_3V+b_2^2\delta_3^2V&=0. \end{aligned}\right\} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (49)$$

Eliminating the coefficients, we obtain, by the usual method,

$$(b_1c_2-b_2c_1)(b_2c-bc_2)(bc_1-b_1c)=0. \quad . \; . \; . \; . \; . \; . \; . \; . \quad (50)$$

But as by hypothesis the three axes are all distinct, this equation cannot be satisfied; and therefore (49) can coexist only on the conditions $\delta_2^2V=0$, $\delta_2\delta_3V=0$, $\delta_3^2V=0$. Hence

if the contact be triaxal it will be superficial. But we may take for two of the axes of triaxal contact the tangents to the two branches of the curve of intersection through P; and for every position of the cutting plane about each of these axes the contact will be three-pointic, viz. two consecutive points of the branch to which the axis is a tangent and one point of the other branch will lie in the plane; whence it follows that, reckoning only arbitrary axes as before, if three-pointic contact be uniaxal it will be superficial. And this method has application to all degrees of contact.

The equations (48) would apparently determine two axes about which three-pointic contact would be circumaxal; but that this is not the case will appear from the actual solution of one of them. In fact the solution of the third equation depends upon the quantity $(\delta_1\delta_2 V)^2-\delta_1^2 V\delta_2^2 V$, in order to develop which we have the following values:—

$$\delta_1^2 V=-\begin{vmatrix} \bar{v}_1, & \bar{u}', & v, \\ u', & \bar{w}_1, & w, \\ v, & w, & . \end{vmatrix}+\theta\begin{vmatrix} v_1, & u', & v, \\ u', & w_1, & w, \\ v, & w, & . \end{vmatrix}$$

$$-\delta_1\delta_2 V=-\begin{vmatrix} \bar{w}', & \bar{v}', & u, \\ \bar{u}', & \bar{w}_1, & w, \\ v, & w, & . \end{vmatrix}+\theta\begin{vmatrix} w', & v', & u, \\ u', & w_1, & w, \\ v, & w, & . \end{vmatrix}$$

$$\delta_2^2 V=-\begin{vmatrix} \bar{u}_1, & \bar{v}', & u, \\ \bar{v}', & \bar{w}_1, & w, \\ u, & w, & . \end{vmatrix}+\theta\begin{vmatrix} u_1, & v', & u, \\ v', & w_1, & w, \\ u, & w, & . \end{vmatrix}$$

Hence, by the method of compound determinants, in the expression $(\delta_1\delta_2 V)^2-\delta_1^2 V\delta_2^2 V$, the term independent of θ

$$=w^2\begin{vmatrix} \bar{u}_1, & \bar{w}', & \bar{v}', & u, \\ \bar{w}', & \bar{v}_1, & \bar{u}', & v, \\ \bar{v}', & \bar{u}', & \bar{w}_1, & w, \\ u, & v, & w, & . \end{vmatrix}=-w^2(\bar{v}_1\bar{w}_1-\bar{u}'^2, \ldots)(u, v, w)^2,$$

the coefficient of θ^2

$$=w^2\begin{vmatrix} u_1, & w', & v', & u, \\ w', & v_1, & u', & v, \\ v', & u', & w_1, & w, \\ u, & v, & w, & . \end{vmatrix}=-w^2(v_1w_1-u'^2, \ldots)(u, v, w)^2;$$

while the coefficient of θ will be found to be

$$=w^2(v_1\bar{w}_1+w_1\bar{v}_1-2u'\bar{u}', \ldots)(u, v, w)^2;$$

so that the whole expression sought

$$\begin{aligned} &= -w^2\{(\bar{v}_1\bar{w}_1-\bar{u}'^2, \ldots)(u, v, w)^2 \\ &\quad -(v_1\bar{w}_1+w_1\bar{v}_1-2u'\bar{u}', \ldots)(u, v, w)(\bar{u}, \bar{v}, \bar{w}) \\ &\quad +(v_1w_1-u'^2, \ldots)(\bar{u}, \bar{v}, \bar{w})^2\} \\ &= -w^2\Phi \text{ suppose.} \end{aligned}$$

This being the case, the solutions of the equations

$$(b\delta_3-c\delta_2)^2V=0, \quad (c\delta_1-a\delta_3)^2V=0, \quad (a\delta_2-b\delta_1)^2V=0$$

may be written in the following forms:—

$$\left.\begin{aligned} b\delta_3^2V-c\delta_2^2V&=\pm u\,c\,\sqrt{-\Phi}, \quad =\mp u\,b\,\sqrt{-\Phi}, \\ c\delta_1^2V-a\delta_3^2V&=\pm v\,a\,\sqrt{-\Phi}, \quad =\mp v\,c\,\sqrt{-\Phi}, \\ a\delta_2^2V-b\,\delta_1^2V&=\pm wb\,\sqrt{-\Phi}, \quad =\mp wa\,\sqrt{-\Phi}, \end{aligned}\right\} \quad \ldots \ldots \quad (51)$$

which involve $\Phi=0$. Φ is therefore a surface which cuts U in a curve, at each point of which there is an axis,

$$a:b:c=\delta_1^2V:\delta_2^2V:\delta_3^2V,$$

about which there is three-pointic contact.

It may be shown also, by the following geometrical construction, that if three-pointic contact be triaxal it will be superficial. If we take three axes, PQ, PQ_1, PQ_2, and draw through each three planes; then if three-pointic contact subsist for each triplet of planes, the contact will be circumaxal for each axis, and therefore triaxal. If we take a fourth axis, PQ_3, the following planes will pass three and three through each of the axes, and will serve for the planes required, viz. the planes

$$PQ_1Q_2, \quad PQ_2Q, \quad PQQ_1, \quad PQQ_3, \quad PQ_1Q_3, \quad PQ_2Q_3,$$

say the planes (A, B, C), .. (A_5, B_5, C_5). Taking the forms $A\delta_1+B\delta_2+C\delta_3$ for $\square$, the conditions for three-pointic contact along each of these planes will be

$$\left.\begin{aligned} (A\delta\ +B\ \delta_2+C\ \delta_3)^2V=0, &\quad (A_3\delta_1+B_3\delta_2+C_3\delta_3)^2V=0, \\ (A_1\delta_1+B_1\delta_2+C_1\delta_3)^2V=0, &\quad (A_4\delta_1+B_4\delta_2+C_4\delta_3)^2V=0, \\ (A_2\delta_1+B_2\delta_2+C_2\delta_3)^2V=0, &\quad (A_5\delta_1+B_5\delta_2+C_5\delta_3)^2V=0. \end{aligned}\right\} \quad \ldots \ldots \quad (52)$$

Eliminating δ_1^2V, δ_2^2V, .. $\delta_2\delta_3V$, .., we obtain the resultant,

$$\begin{vmatrix} A^2, & B^2, \ldots B\,C, \ldots \\ A_1^2, & B_1^2, \ldots B_1C_1, \ldots \\ \vdots & \\ A_5^2, & B_5^2, \ldots B_5C_5, \ldots \end{vmatrix} =0, \quad \ldots \ldots \ldots \quad (53)$$

which is the condition that the six planes should all touch a cone of the second degree. But the planes in question pass three and three through four lines; and as it is impossible through any one line to draw more than two planes touching a cone of the second

degree, the equations above written (52) cannot be satisfied except on the conditions $\delta_1^2\mathrm{V}=0$, $\delta_2^2\mathrm{V}=0$, .. $\delta_2\delta_3\mathrm{V}=0$, .., which are in fact the conditions for superficial contact.

There is another more general way in which the subject may be regarded. In fact if α, β, γ (or, if we prefer so to state it, if A, B, C) no longer have the significations originally given to them, but represent the differential coefficients of an auxiliary surface W; say, if

$$\partial_x\mathrm{W}=\mathrm{u},\quad \partial_y\mathrm{W}=\mathrm{v},\quad \partial_z\mathrm{W}=\mathrm{w},\quad \partial_t\mathrm{W}=\mathrm{k}, \quad . \quad . \quad . \quad . \quad . \quad . \quad (54)$$

then the equations

$$\mathrm{V}=0,\ (\mathrm{u}\delta_1+\mathrm{v}\delta_2+\mathrm{w}\delta_3)\mathrm{V}=0,\ (\mathrm{u}\delta_1+\mathrm{v}\delta_2+\mathrm{w}\delta_3)^2\mathrm{V}=0, \quad . \quad . \quad . \quad . \quad . \quad (55)$$

will no longer express the conditions for two-, three-, .. pointic contact of the curves of section made by the plane (α, β, γ) or the plane (A, B, C), but the contact of the curves of section made by the surface W. And as the surface W is perfectly arbitrary, the formulæ will apply to any curve drawn at pleasure from the point P on the surface U. It is to be borne in mind that in expanding the expression for three-pointic contact we shall obtain

$$\begin{aligned}(\mathrm{u}\delta_1+\ldots)^2&=(\mathrm{u}\delta_1+\ldots)\mathrm{u}\delta_1\mathrm{V}+(u\delta_1+\ldots)\mathrm{v}\delta_2\mathrm{V}+\ldots\\&+(\mathrm{u}^2\delta_1^2+\mathrm{V}^2\delta_2^2+\ldots 2\mathrm{uv}\delta_1\delta_2+\ldots)\mathrm{V};\end{aligned}$$

but in the only case which possesses much interest, viz. when the two-pointic contact at the point P is superficial, we have $\delta_1\mathrm{V}=0$, $\delta_2\mathrm{V}=0$, $\delta_3\mathrm{V}=0$; and consequently

$$(\mathrm{u}\delta_1+\ldots)^2\mathrm{V}=(\mathrm{u}^2\delta_1^2+\mathrm{v}^2\delta_2^2+\ldots 2\mathrm{uv}\delta_1\delta_2+\ldots)\mathrm{V}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (56)$$

which is of the same form as the expression derived in the case of plane sections. And as the operators δ_1, δ_2, .. are unchanged, and are subject to the same identical relations as before, the conditions of contact now considered will be susceptible of the same transformations (the transformations (13–16) excepted) as those considered before. From these, therefore, we may draw the following conclusion:—

Consider two surfaces, U, V, having superficial two-, three-, .. pointic contact at a point P; from P draw any number of curves arbitrarily on U; two, three, .. consecutive points of these curves will, in consequence of the superficial contact, lie also on V. This being so, if for any three, four, .. of the curves an additional consecutive point lies on V, then the same will be the case for all the curves, and there will be superficial three-, four-, .. pointic contact between U and V at the point P.

This may be also stated in the following form:—

If two surfaces, U, V, have two-, three-, .. pointic superficial contact at a point P, and if through P we draw any number of surfaces arbitrarily, the curves of section on U and V which correspond to one another will, in consequence of the superficial contact, have two-, three-, .. pointic contact. This being the case, if any three-, four-, .. corresponding curves have three-, four-, .. pointic contact, then all will have three-, four-, .. pointic contact; and there will be three-, four-, .. pointic superficial contact between U and V at the point P.

This theorem for the case of three-pointic contact was given by DUPIN, 'Développements de Géométrie,' p. 12.

§ 4. *On Surfaces having Superficial Contact with given Surfaces.*

It is well known that at any point P of a surface U we may in general determine a plane V touching, or, in terms of this memoir, having two-pointic superficial contact with U. This suggests the question whether surfaces V of other degrees may not be determined having superficial contact of higher degrees with U at a point P.

The number of conditions for a 1, 2, .. p-pointic superficial contact has been shown above to be

$$1,\ 3,\ 6,\ ..\ \frac{p(p+1)}{1\,.\,2}.$$

Now the number of independent constants in the equation of a surface V of the degree 1, 2, .. m, is

$$3,\ 9,\ 19,\ ..\ \frac{(m+1)(m+2)(m+3)}{1\,.\,2\,.\,3}-1\,;$$

so that, employing the equations which express the conditions of contact for determining the constants of V, we shall meet with the following cases. First, if the number of conditions be equal to the number of constants, there will be a determinate surface V having a superficial contact of the degree under consideration (say p) with U at the point P. Secondly, if the number of conditions exceed that of the constants by unity, the constants may be eliminated, and the result will be an equation between the coordinates; in other words, an equation to a surface which will cut U in a curve at every point of which a surface V may be drawn having p-pointic superficial contact with U. Thirdly, if the number of conditions exceed that of the constants by 2, we may eliminate the constants in two ways, and obtain two resulting equations, which will represent two surfaces mutually cutting U in a finite number of points, at each of which a surface V may be drawn having p-pointic superficial contact with U. Lastly, if the number of conditions exceed that of the constants by more than two, we shall obtain a number of resulting equations equal to that excess. From these, together with the equations U=0, V=0, the variables may be eliminated; so that the number of resultants less 2 will represent the number of conditions which must subsist among the constants of U, in order that it may be possible to draw such a surface V. This being the case, there will be a determinate surface V of the degree m having p-pointic superficial contact with U, (1) at any point on U, or (2) along a certain curve on U, or (3) only at a finite number of points on U, according as the expression

$$\frac{p(p+1)}{1.2}-\frac{(m+1)(m+2)(m+3)}{1.2.3}+1=0,\ 1,\ 2\,;$$

or, clearing denominators, according as

$$3p(p+1)-m^3-6m^2-11m=0,\ 6,\ 12. \quad \ldots\ldots \quad (57)$$

Now it is obvious from the signs of the terms on the left-hand side of this equation that the result cannot be positive if p be less than $2m$; beginning therefore with $p=2m$, we obtain

$$-m^3+6m^2-5m=0,\ 6,\ 12;$$

or, resolving into factors, we have the three cases

$$m(m-1)(m-5)=0,$$
$$(m-2)(m^2-4m+3)=0,$$
$$(m-3)(m-4)(m+1)=0.$$

Next, let $p=2m+1$; then, substituting this value in the equation (57), we obtain

$$-m^3+6m^2+7m+6=0,\ 6,\ 12;$$

or resolving into factors so far as possible, we have the three cases

$$m^3-6m^2-7m-6=0,$$
$$(m-7)(m+1)=0,$$
$$m^3-6m^2-7m+6=0,$$

the first and last of which give no solutions in positive whole numbers.

This appears to exhaust all the solutions of (57) in positive whole numbers. Recapitulating the foregoing results, we may form the following Table:—

Degree of contact.	Number of conditions.	Degree of V.	Number of constants.	Difference conds.–consts.	Superficial contact possible.
2	3	1	3	0	At every point on U.
4	10	2	9	1	Along a curve on U.
6	21	3	19	2	At a finite number of points on U.
8	36	4	34	2	
10	55	5	55	0	At every point on U.
15	120	7	119	1	Along a curve on U.

Such is the general theory. But it is probable that it undergoes modifications in each particular case; it certainly does so in the only case fully examined here, viz. that of a quadric having four-pointic contact with U.

In fact, inasmuch as the equations, whereby the constants are ultimately determined, are linear the solution is in every case unique. But four-pointic contact will subsist if we consider the quadric to consist of the tangent plane taken twice; and as the solution is unique, no other quadric can in general be drawn having four-pointic contact. Further, since a tangent plane can in general be drawn at every point on U, the quadric of four-pointic contact (viz. the tangent plane taken twice) exists generally; and the condition (viz. difference, conditions—constants=1) restricting it to a curve on U must be satisfied

identically. Similar remarks apply to contact of the degrees 6, 8, 10; but not apparently to that of the degree 15.

It will be worth while to examine the case of four-pointic contact more in detail; and for this purpose the special transformation of the operation $\square^2\mathrm{V}$, employed in the memoir before quoted, appears to be best adapted. The following method of effecting that transformation is perhaps more expeditious and direct than the process used in the memoir itself.

Taking for $\square$ the form $\mathrm{A}\delta_1+\mathrm{B}\delta_2+\mathrm{C}\delta_3$, we have

$$\square^2\mathrm{V}=\square\begin{vmatrix} \mathrm{A}, & u, & \partial_x \\ \mathrm{B}, & v, & \partial_y \\ \mathrm{C}, & w, & \partial_z \end{vmatrix}=\begin{vmatrix} \square\mathrm{A}, & u, & \partial_x \\ \square\mathrm{B}, & v, & \partial_y \\ \square\mathrm{C}, & w, & \partial_z \end{vmatrix}+\begin{vmatrix} \mathrm{A}, & \square u, & \partial_x \\ \mathrm{B}, & \square v, & \partial_y \\ \mathrm{C}, & \square w, & \partial_z \end{vmatrix}+\begin{vmatrix} \mathrm{A}, & u, & \square\partial_x \\ \mathrm{B}, & v, & \square\partial_y \\ \mathrm{C}, & w, & \square\partial_z \end{vmatrix}.$$

But by the equations (11) of the memoir,

$$\varpi\square\mathrm{A}=\begin{vmatrix} \mathrm{A}, & u, & \alpha\mathrm{A}-\alpha\mathrm{A}, \\ \mathrm{B}, & v, & \alpha\mathrm{B}-\beta\mathrm{A}, \\ \mathrm{C}, & w, & \alpha\mathrm{C}-\gamma\mathrm{A}, \end{vmatrix}=-\begin{vmatrix} \mathrm{A}, & u, & \alpha, \\ \mathrm{B}, & v, & \beta, \\ \mathrm{C}, & w, & \gamma, \end{vmatrix}\mathrm{A}=-\varpi\begin{vmatrix} \alpha, & \alpha', & u, \\ \beta, & \beta', & v, \\ \gamma, & \gamma', & w, \end{vmatrix}\mathrm{A};$$

whence

$$\begin{vmatrix} \square\mathrm{A}, & u, & \partial_x \\ \square\mathrm{B}, & v, & \partial_y \\ \square\mathrm{C}, & w, & \partial_z \end{vmatrix}\mathrm{V}=-\begin{vmatrix} \alpha, & \alpha', & u, \\ \beta, & \beta', & v, \\ \gamma, & \gamma', & w, \end{vmatrix}\begin{vmatrix} \mathrm{A}, & u, & \partial_x \\ \mathrm{B}, & v, & \partial_y \\ \mathrm{C}, & w, & \partial_z \end{vmatrix}\mathrm{V}=-\begin{vmatrix} \alpha, & \alpha', & u, \\ \beta, & \beta', & v, \\ \gamma, & \gamma', & w. \end{vmatrix}\square\mathrm{V}=0,$$

since by hypothesis $\square\mathrm{V}=0$. Again,

$$\square u=\begin{vmatrix} \mathrm{A}, & u, & u_1, \\ \mathrm{B}, & v, & w', \\ \mathrm{C}, & w, & v', \end{vmatrix},\quad \square v=\begin{vmatrix} \mathrm{A}, & u, & w', \\ \mathrm{B}, & v, & v_1, \\ \mathrm{C}, & w, & u', \end{vmatrix},\quad \square w=\begin{vmatrix} \mathrm{A}, & u, & v', \\ \mathrm{B}, & v, & u', \\ \mathrm{C}, & w, & w_1; \end{vmatrix}$$

whence, remembering that (on the supposition $\square\mathrm{V}=0$) $\partial_x\mathrm{V}=\theta u$, $\partial_y\mathrm{V}=\theta v$, $\partial_z\mathrm{V}=\theta w$, we derive the following:

$$\begin{vmatrix} \mathrm{A}, & \square u, & \partial_x \\ \mathrm{B}, & \square v, & \partial_y \\ \mathrm{C}, & \square w, & \partial_z \end{vmatrix}\mathrm{V}=\theta\begin{vmatrix} \mathrm{A}, & \square u, & u, \\ \mathrm{B}, & \square v, & v, \\ \mathrm{C}, & \square w, & w, \end{vmatrix}=-\theta\begin{vmatrix} u_1, & w', & v', & u, & \mathrm{A}, \\ w', & v_1, & u', & v, & \mathrm{B}, \\ v', & u', & w_1, & w, & \mathrm{C}, \\ u, & v, & w, & . & . \\ \mathrm{A}, & \mathrm{B}, & \mathrm{C}, & . & . \end{vmatrix}=-\frac{\theta t^2}{(n-1)^2}\mathrm{H},$$

where

$$\mathrm{H}=\begin{vmatrix} u_1, & w', & v', & l', & \mathrm{A}, \\ w', & v'_1, & u', & m', & \mathrm{B}, \\ v', & u', & w_1, & u', & \mathrm{C}, \\ l', & m', & u', & k_1, & \mathrm{D}, \\ \mathrm{A}, & \mathrm{B}, & \mathrm{C}, & \mathrm{D}, & . \end{vmatrix}.$$

Again, if in the following expressions $\partial_x, \partial_y, \partial_z, \partial_t$ be understood to affect V alone, then

$$\begin{vmatrix} \mathrm{A}, & u, & \square\partial_x, \\ \mathrm{B}, & v, & \square\partial_y, \\ \mathrm{C}, & w, & \square\partial_z, \end{vmatrix}\mathrm{V}=\begin{vmatrix} u_1, & w', & v', & u, & \mathrm{A}, & \partial_x, \\ w', & v_1, & u', & v, & \mathrm{B}, & \partial_y, \\ v', & u', & w_1, & w, & \mathrm{C}, & \partial_z, \\ u, & v, & w, & . & . & . \\ \mathrm{A}, & \mathrm{B}, & \mathrm{C}, & . & . & . \\ \partial_x, & \partial_y, & \partial_z, & . & . & . \end{vmatrix}\mathrm{V}=\frac{t}{n-1}\begin{vmatrix} u_1, & w', & v', & l', & \mathrm{A}, & \partial_x, \\ w', & v_1, & u', & m', & \mathrm{B}, & \partial_y, \\ v', & u', & w_1, & u', & \mathrm{C}, & \partial_z, \\ u, & v, & w, & k, & . & . \\ \mathrm{A}, & \mathrm{B}, & \mathrm{C}, & \mathrm{D}, & . & . \\ \partial_x, & \partial_y, & \partial_z, & \partial_t-\frac{\mathrm{D}}{t}, & . & . \end{vmatrix}$$

where $\mathrm{D}=x\partial_x+y\partial_y+z\partial_z+t\partial_t$. Also, by similar processes, the above expression may be further transformed as follows:

$$=\frac{t^2}{(n-1)^2}\begin{vmatrix} u_1, & w', & v', & l', & \mathrm{A}, & \partial_x, \\ w', & v_1, & u', & m', & \mathrm{B}, & \partial_y, \\ v', & u', & w_1, & u', & \mathrm{C}, & \partial_z, \\ l', & m', & u', & k_1, & \mathrm{D}, & \partial_t-\frac{\mathrm{D}}{t}, \\ \mathrm{A}, & \mathrm{B}, & \mathrm{C}, & \mathrm{D}, & . & . \\ \partial_x, & \partial_y, & \partial_z, & \partial_t-\frac{\mathrm{D}}{t}, & . & . \end{vmatrix}\mathrm{V}=\frac{t^2}{(n-1)^2}\left(\Delta\mathrm{V}-2\,\frac{m-1}{n-1}\,\theta\mathrm{H}\right),$$

where

$$\Delta=\begin{vmatrix} u_1, & w', & v', & l', & \mathrm{A}, & \partial_x, \\ w', & v_1, & u', & m', & \mathrm{B}, & \partial_y, \\ v', & u', & w_1, & u', & \mathrm{C}, & \partial_z, \\ l', & m', & u', & k_1, & \mathrm{D}, & \partial_t, \\ \mathrm{A}, & \mathrm{B}, & \mathrm{C}, & \mathrm{D}, & . & . \\ \partial_x, & \partial_y, & \partial_z, & \partial_t, & . & . \end{vmatrix}$$

So that finally the expression $\square^2\mathrm{V}=0$, combined with $\mathrm{V}=0$, $\square\mathrm{V}=0$, is reduced to

$$\Delta\mathrm{V}-\left(1+2\frac{m-1}{n-1}\right)\theta\mathrm{H}=0,$$

where

$$\theta = \frac{\partial_x V}{u} = \frac{\partial_y V}{v} = \frac{\partial_z V}{w} = \frac{\partial_t V}{k},$$

which agree with the results obtained in the memoir.

In order to determine a quadric V which shall have superficial four-pointic contact with the surface U, let H_{11} be the value of H when α, β, γ, δ are written for A, B, C, D respectively in the last line and the last column of H; let H_{12} be the value of H when α, β, γ, δ are written for A, B, C, D respectively in the last line or the last column, and α', β', γ', δ' in the last column or the last line of H; and let H_{22} be the value of H when α', β', γ', δ' are written for A, B, C, D respectively in the last line and the last column of H. Further, let

$$\partial_x H = p, \quad \partial_y H = q, \quad \partial_z H = r, \quad \partial_t H = s, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (58)$$

the differentiations being effected (as was shown in the memoir to be permissible) without reference to A, B, C, D. Lastly, if $p_{11}, \ldots, p_{12}, \ldots, p_{22}, \ldots$ be the values of $p, \ldots$ when H becomes H_{11}, H_{12}, H_{22}, respectively, let

$$X, Y, Z, T = \begin{array}{cccc} A, & B, & C, & D, \\ & & w, & k, \end{array} \Big\|, \; P, Q, R, S = - \Big\| \begin{array}{ccc|cccc} A, & u, & p, & u_1, & w', & v', & l', \\ B, & v, & q, & w', & v_1, & u', & m, \\ C, & w, & r, & v', & & & \\ D, & k, & s, & l'. & & & \end{array} \Big\| \quad (59)$$

That is to say, X, Y, Z, T are the determinants formed from the matrix opposite to them by omitting each of the columns in order; and P, Q, R, S are the negatives of the determinants formed from the matrix opposite to them by omitting each of the columns 4, 5, 6, 7 in order, and always retaining the columns 1, 2, 3.

This being premised, the conditions which the coefficients of the quadric

$$V = (a, b, c, d, f, g, h, l, m, n)(x, y, z, t)^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (60)$$

must satisfy in order that four-pointic contact may subsist between the two curves of section of the surfaces U, V made by the plane $Ax + By + Cz + Dt = 0$ will be, as proved in the memoir above quoted,

$$\left.\begin{array}{l} (uX - xP)a + (uY - yP)h + (uZ - zP)g + (uT - tP)l = 0, \\ (vX - xQ)h + (vY - yQ)b + (vZ - zQ)f + (vT - tQ)m = 0, \\ (wX - xR)g + (wY - yR)f + (wZ - zR)c + (wT - tR)n = 0, \\ (kX - xS)l + (kY - yS)m + (kZ - zS)n + (kT - tS)d = 0; \end{array}\right\} \quad . \quad . \quad . \quad (61)$$

and the contact will be circumaxal if the foregoing equations are made independent of $\varpi' : \varpi$. If, therefore, we represent by $X_{111}, \ldots P_{111}, \ldots$; $X_{112}, \ldots P_{112}, \ldots$; $X_{122}, \ldots P_{122}, \ldots$; $X_{222}, \ldots P_{222}, \ldots$ the coefficients of the powers of $\varpi' : \varpi$ in $X, \ldots P, \ldots$ respectively, we shall have four equations in the place of each one of the above group—apparently twelve

equations in all. These, however, are equivalent to only nine, as may be thus shown. Taking the first, and equating to zero the coefficients of the several powers of $\varpi' : \varpi$, and eliminating a, h, g, l, we obtain the condition,

$$\left|\begin{array}{llll} uX_{111}-xP_{111}, & uY_{111}-yP_{111}, & uZ_{111}-zP_{111}, & uT_{111}-tP_{111}, \\ uX_{112}-xP_{112}, & uY_{112}-yP_{112}, & uZ_{112}-zP_{112}, & uT_{112}-tP_{112}, \\ uX_{122}-xP_{122}, & uY_{122}-yP_{122}, & uZ_{122}-zP_{122}, & uT_{122}-tP_{122}, \\ uX_{222}-xP_{222}, & uY_{222}-yP_{222}, & uZ_{222}-zP_{222}, & uT_{222}-tP_{222}, \end{array}\right|=0; \quad . \quad . \quad (62)$$

and it is not difficult to see that omitting the factor u^3, and employing the relations $u_1X+w'Y+v'Z+l'T=P$ &c., this expression may be reduced to the following form:—

$$\begin{array}{lllll} u\ , & x\ , & y\ , & z\ , & t\ , \\ P_{111}, & X_{111}, & Y_{111}, & Z_{111}, & T_{111}, \\ P_{112}, & X_{112}, & Y_{112}, & Z_{112}, & T_{112}, \\ P_{122}, & X_{122}, & Y_{122}, & Z_{122}, & T_{122}, \\ P_{222}, & X_{222}, & Y_{222}, & Z_{222}, & T_{222}, \end{array} \qquad \begin{array}{llll} X_{111}, & Y_{111}, & Z_{111}, & T_{111}, \\ X_{112}, & Y_{112}, & Z_{112}, & T_{112}, \\ X_{122}, & Y_{122}, & Z_{122}, & T_{122}, \\ X_{222}, & Y_{222}, & Z_{222}, & T_{222}, \end{array} \qquad (63)$$

which vanishes identically, since $uX_{111}+vY_{111}+wZ_{111}+kT_{111}=0$ &c.

The four equations derived from each of (61) are consequently reduced to three, and the whole number of equations connecting the ten coefficients of U to nine, the proper number for the determination of their nine ratios.

This being the case, we may take as the equations for determining the ratios a : h : g : l the following, viz.

$$\begin{aligned} (uX_{111}-xP_{111})\mathrm{a}+(uY_{111}-yP_{111})\mathrm{h}+(uZ_{111}-zP_{111})\mathrm{g}+(uT_{111}-tP_{111})\mathrm{l}&=0, \\ (uX_{112}-xP_{112})\mathrm{a}+(uY_{112}-yP_{112})\mathrm{h}+(uZ_{112}-zP_{112})\mathrm{g}+(uT_{112}-tP_{112})\mathrm{l}&=0, \\ (uX_{122}-xP_{122})\mathrm{a}+(uY_{122}-yP_{122})\mathrm{h}+(uZ_{122}-zP_{122})\mathrm{g}+(uT_{122}-tP_{122})\mathrm{l}&=0; \end{aligned}$$

and the quantity to which l is proportional will then be

$$\begin{array}{lll} uX_{111}-xP_{111}, & uY_{111}-yP_{111}, & uZ_{111}-zP_{111}, \\ uX_{112}-xP_{112}, & uY_{112}-yP_{112}, & uZ_{112}-zP_{112}, \\ uX_{122}-xP_{122}, & uY_{122}-yP_{122}, & uZ_{122}-zP_{122}, \end{array}$$

which, omitting the factor u^2, is equal to

$$\begin{array}{llll} u\ , & x\ , & y\ , & z\ , \\ P_{111}, & X_{111}, & Y_{111}, & Z_{111}, \\ P_{112}, & X_{112}, & Y_{112}, & Z_{112}, \end{array} \qquad \begin{array}{llll} -(n-2)n+l't\ , & x\ , & y\ , & z\ , \\ l'T_{111}, & X_{111}, & Y_{111}, & Z_{111}, \\ l'T_{112}, & X_{112}, & Y_{112}, & Z_{112}, \\ l'T_{122}, & X_{122}, & Y_{122}, & Z_{122} \end{array} = -(n-2)n \begin{array}{lll} X_{111}, & Y_{111}, & Z_{111}, \\ X_{112}, & Y_{112}, & Z_{112}, \\ X_{122}, & Y_{122}, & Z_{122}, \end{array}$$

Calling the coefficient of $-(n-2)n$ in the last expression (X, Y, Z), and forming simila

expressions in Y, Z, T, &c., we shall obtain the following values for the ratios sought, viz.—

$$\frac{\mathrm{a}}{(\mathrm{Y}, \mathrm{Z}, \mathrm{T})}=\frac{\ }{(\mathrm{Z}, \mathrm{X}, \mathrm{T})}=\frac{\ }{(\mathrm{X}, \mathrm{Y}, \mathrm{T})}=\frac{\ }{(\mathrm{X}, \mathrm{Y}, \mathrm{Z})}$$

But

$$\begin{aligned} k(\mathrm{Y}, \mathrm{Z}, \mathrm{T}) &= -u(\mathrm{X}, \mathrm{Y}, \mathrm{Z}), \\ k(\mathrm{Z}, \mathrm{X}, \mathrm{T}) &= -v(\mathrm{X}, \mathrm{Y}, \mathrm{Z}), \\ k(\mathrm{X}, \mathrm{Y}, \mathrm{T}) &= -w(\mathrm{X}, \mathrm{Y}, \mathrm{Z}). \end{aligned}$$

Hence, omitting the common factor (X, Y, Z), we have

$$\frac{\mathrm{a}}{u}=\frac{\mathrm{h}}{v}=\frac{\mathrm{g}}{w}=\frac{\mathrm{l}}{k}; \quad \ldots \ldots \ldots \ldots \quad (65)$$

and proceeding in a similar manner with the equations in h, b, f, m; g, f, c, n; l, m, n, d, it will be found that, when the quantity (X, Y, Z) does not vanish,

$$\mathrm{V}=(\mathrm{a}, \mathrm{b}, \ldots, \mathrm{f}, \ldots \mathrm{l}, \ldots)(x, y, z, t)^2=(ux+vy+wz+kt)^2; \quad \ldots \quad (66)$$

that is to say, that the only quadric which in general has a superficial four-pointic contact with U at any given point P is the tangent plane taken twice.

From the relations given above, it appears that if any one of the equations

$$(\mathrm{Y}, \mathrm{Z}, \mathrm{T})=0, \quad (\mathrm{Z}, \mathrm{X}, \mathrm{T})=0, \quad (\mathrm{X}, \mathrm{Y}, \mathrm{T})=0, \quad (\mathrm{X}, \mathrm{Y}, \mathrm{Z})=0 \quad . \ . \quad (67)$$

is satisfied, then all are satisfied; so that it will be sufficient to study any one of them.

Although I have not succeeded in reducing the expression (X, Y, Z) to any very simple form, it may still be worth while to show how it may be extricated from the condition of a compound determinant. With a view to this, we may write down the values of $\mathrm{X}_{111}, \ldots$ in full, viz.:—

$$\mathrm{X}_{111}=\begin{vmatrix} \beta, & \gamma, & \delta, \\ v, & w, & k, \\ q_{11}, & r_{11}, & s_{11}, \end{vmatrix} \qquad \mathrm{Y}_{111}=\begin{vmatrix} \gamma, & \alpha, & \delta, \\ w, & u, & k, \\ r_{11}, & p_{11}, & s_{11}, \end{vmatrix} \qquad \mathrm{Z}_{111}=\ldots, \mathrm{T}_{111}=\ldots$$

$$\mathrm{X}_{112}=2\begin{vmatrix} , & \gamma, & \delta, \\ v, & w, & k, \\ q_{12}, & r_{12}, & s_{12}, \end{vmatrix}+\begin{vmatrix} \beta', & \gamma', & \delta', \\ v, & w, & k, \\ q_{11}, & r_{11}, & s_{11}, \end{vmatrix}, \quad \mathrm{Y}_{112}=2\begin{vmatrix} \gamma, & \alpha, & \delta, \\ w, & u, & k, \\ r_{12}, & p_{12}, & s_{12}, \end{vmatrix}+\begin{vmatrix} \gamma', & \alpha', & \\ w, & u, & k, \\ r_{11} & & \end{vmatrix} \quad \mathrm{Z}_{112}=\ldots, \mathrm{T}_{112}=\ldots$$

$$\mathrm{X}_{122}=2\begin{vmatrix} \beta', & \gamma', & \delta', \\ v, & w, & k, \\ q_{12}, & r_{12}, & s_{12}, \end{vmatrix}+\begin{vmatrix} \beta, & \gamma, & \delta, \\ v, & w, & k, \\ q_{22}, & r_{22}, & s_{22}, \end{vmatrix}, \quad \mathrm{Y}_{122}\begin{vmatrix} \gamma', & \alpha', & \delta', \\ w, & u, & k, \\ r_{12}, & p_{12}, & s_{12}, \end{vmatrix}+\begin{vmatrix} \gamma, & \alpha & \\ & , & k, \\ r_{22}, & p_{22} & \end{vmatrix} \quad \mathrm{Z}_{122}=\ldots, \mathrm{T}_{122}=\ldots$$

$$\mathrm{X}_{222}=\begin{vmatrix} \beta', & \gamma', & \delta', \\ v, & w, & k, \\ q_{22}, & r_{22}, & s_{22}, \end{vmatrix} \qquad \mathrm{Y}_{222}=\begin{vmatrix} \gamma', & \alpha', & \delta', \\ w, & u & \\ r_{22}, & p_{22} & \end{vmatrix} \qquad \mathrm{Z}_{222}=\ldots, \mathrm{T}_{222}=$$

This being so, let

$$\left.\begin{array}{l}
\begin{vmatrix} \alpha, & \beta, & \gamma, & \delta, \\ \alpha', & \beta', & \gamma', & \delta', \\ u, & v, & w, & k, \\ p_{11}, & q_{11}, & r_{11}, & s_{11}, \end{vmatrix}=\Upsilon, \quad
\begin{vmatrix} \alpha, & \beta, & \gamma, & \delta, \\ \alpha', & \beta', & \gamma', & \delta', \\ u, & v, & w, & k, \\ p_{12}, & q_{12}, & r_{12}, & s_{12}, \end{vmatrix}=\Upsilon_1, \quad
\begin{vmatrix} \alpha, & \beta, & \gamma, & \delta, \\ \alpha', & \beta', & \gamma', & \delta', \\ u, & v, & w, & k, \\ p_{22}, & q_{22}, & r_{22}, & s_{22}, \end{vmatrix}=\Upsilon_2, \\
\begin{vmatrix} \alpha, & \beta, & \gamma, & \delta, \\ u, & v, & w, & k, \\ p_{12}, & q_{12}, & r_{12}, & s_{12}, \\ p_{22}, & q_{22}, & r_{22}, & s_{22}, \end{vmatrix}=\Omega_2, \quad
\begin{vmatrix} \alpha, & \beta, & \gamma, & \delta, \\ u, & v, & w, & k, \\ p_{22}, & q_{22}, & r_{22}, & s_{22}, \\ p_{11}, & q_{11}, & r_{11}, & s_{11}, \end{vmatrix}=-2\Omega_1, \quad
\begin{vmatrix} \alpha, & \beta, & \gamma, & \delta, \\ u, & v, & w, & k, \\ p_{11}, & q_{11}, & r_{11}, & s_{11}, \\ p_{12}, & q_{12}, & r_{12}, & s_{12}, \end{vmatrix}=\Omega.
\end{array}\right\} \quad (68)$$

Also let Ω'_2, Ω'_1, Ω' represent the expressions obtained by writing α', β', γ', δ' for $\alpha, \beta, \gamma, \delta$ respectively in the first lines of $\Omega_2, \Omega_1, \Omega$. Then it will be found, by the method of compound determinants, that

$$\begin{vmatrix} X_{111}, & Y_{111}, \\ X_{112}, & Y_{112}, \end{vmatrix}=2\Omega \begin{array}{ll} \gamma, & \delta, \\ w, & k, \end{array} +\Upsilon \begin{array}{l} w, \\ r_{11} \end{array} \qquad \begin{array}{lll} \gamma, & \delta, & \Upsilon, \\ w, & k, & . \\ r_{11}, & s_{11}, & 2\Omega, \end{array}$$

whence

$$\begin{array}{lll} X_{111}, & Y_{111}, & Z_{111}, \\ X_{112}, & Y_{112}, & Z_{112}, \\ X_{122}, & Y_{122}, & Z_{122}, \end{array} \qquad \begin{array}{lll} 2\Upsilon, & \delta, & \Upsilon, \\ . & k, & . \\ 2\Omega'+2\Omega_1, & s_{11}, & 2\Omega, \end{array} =2k\{2\Upsilon_1\Omega-\Upsilon(\Omega_1+\Omega')\};$$

similarly,

$$\begin{array}{lll} X_{111}, & Y_{111}, & Z_{111}, \\ X_{112}, & Y_{112}, & Z_{112}, \\ X_{222}, & Y_{222}, & Z_{222}, \end{array} =2k(\Upsilon_2\Omega-\Upsilon\Omega'_1);$$

both of which, when equated to zero, are comprised in the system

$$\frac{\Omega}{\Upsilon}=\frac{\Omega'+\Omega_1}{2\Upsilon_1}=\frac{\Omega'_1}{\Upsilon_2}. \quad \ldots \ldots \quad (69)$$

Similarly, taking the determinants

$$\begin{array}{lll} X_{112}, & Y_{112}, & Z_{112}, \\ X_{122}, & Y_{122}, & Z_{122}, \\ X_{222}, & Y_{222}, & Z_{222}, \end{array} \qquad \begin{array}{lll} X_{111}, & Y_{111}, & Z_{111}, \\ X_{122}, & Y_{122}, & Z_{122}, \\ X_{222}, & Y_{222}, & Z_{222}, \end{array} =0,$$

we should arrive at the system

$$\frac{\Omega_1}{\Upsilon}=\frac{\Omega'_1+\Omega_2}{2\Upsilon_1}=\frac{\Omega'_2}{\Upsilon_2}. \quad \ldots \ldots \quad (70)$$

XIII. *On the Organization of the Fossil Plants of the Coal-measures.*—Part III. Lycopodiaceæ (*continued*). *By* W. C. Williamson, *F.R.S.*, *Professor of Natural History, Owens College, Manchester.*

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In the last memoir which I laid before the Royal Society I described a number of forms of Lepidodendroid plants from the Coal-measures, without making any material attempt to ascertain the relationship which they bore to each other. I now propose to carry the subject somewhat further, and to show that some of these apparently varied forms of Lycopodiaceæ merely represent identical or closely allied plants in different stages of their growth. The discovery of some remarkable beds in Burntisland, by George Grieve, Esq., and his persistent kindness in supplying me abundantly with the raw material upon which I could work, have enabled me to do this in a manner, at least, satisfactory to myself. Upon the geology of these remarkable beds I will not now enter, beyond saying that they appear to have been patches of peat belonging to the lower Burdiehouse series, which are now imbedded in masses of volcanic amygdaloid. The stratum, where unaltered by contact with the lava, is little more than a mass of vegetable fragments, the minute structure of most of which is exquisitely preserved. The more perfect remains that are capable of being identified belong to but few types. The most abundant of these are the young twigs of a *Lepidodendron*, portions of the stem of a *Diploxylon*, stems of a remarkable Lycopodiaceous plant belonging to my new genus *Dictyoxylon* (but which, for reasons to be stated in a future memoir, I propose to unite with Corda's genus *Heterangium*, under the name of *H. Grievii*), and fragments of *Stigmaria ficoides*. Along with these occur, but more rarely, several other curious Lycopodiaceous and Fern stems, and those of an articulated plant, which I believe to be an *Asterophyllites*; also some true Lepidostrobous fruits and myriads of caudate macrospores belonging to the *Lepidostrobi*.

The first point to be noted is that all the Lepidodendroid branches are young twigs. No one example of a large stem has been found presenting exactly the same structure as these small branches, which, as already stated, are so abundant. On the other hand, all the *Diploxylons* are large branches or matured stems. These facts at once suggested the inquiry whether the two plants referred to might not be complementary to each other. A careful and very extended study of a large number of specimens has convinced me that such is the case. I have made more than a hundred sections of the two forms, and the result has been a remarkably clear testimony that the *Lepidodendra* are the twigs and young branches of the *Diploxylon*-stems. I am also led to the con-

clusion that the *Lepidostrobi*, with their peculiar macrospores and microspores, belong to the same plant. I will examine each of these forms in detail.

Plate XLI. fig. 1 represents a section, rather less than a quarter of an inch in length, of a compressed twig of a *Lepidodendron*. Nearly all the stems found in these beds are thus compressed, the peat and its contents having apparently been heavily weighted by the superimposed volcanic masses. In the case of the larger *Diploxylon*-stem the central woody cylinders have been strong enough to resist the pressure, their thick cortical layers alone having yielded to it. The smaller *Diploxylons* are somewhat more compressed, as is also the case with the Lepidodendroid twigs.

In the section under consideration we have a central vascular cylinder (fig. 1, *c*), in the middle of which is a small vacant space. In other and similar sections this vacant area is occupied by a very delicate form of cellular tissue. The vascular cylinder consists of an aggregation of barred vessels not arranged in radiating lines; it is surrounded by a mass of parenchyma, the innermost portion of which (*g*) is somewhat different from the rest. This parenchyma is continuous with that of the bases of the leaves (*l*), whilst at *l'* we have sections of the free extremities of several of the leaflets. Such are the broad features of the majority of these sections; but a closer study of a large number of specimens reveals differences which it may be well to study in the order of their development.

Plate XLI. fig. 2 represents the extreme tip of a very slender twig, not more than one twelfth of an inch in diameter. In its centre is a small bundle of barred vessels; the rest of the section is composed of cells whose maximum diameter is rarely ·0012, those of the epidermal surface being smaller and more dense than those of the interior of the section. The bases of the leaves (*l*), with the exception of that marked *l'*, exhibit none of the peculiar form which characterizes them when perfect, as seen in fig. 1, *l*. Fig. 3 represents the central vascular bundle of a specimen in all respects similar to fig. 2. It consists of an irregular cylinder of barred vessels of various sizes; but the transverse section of the largest is not more than ·0025 at its greatest diameter, whilst others are even less than ·0005*. In the centre of the bundle is a very small area (*a*) of irregular shape, in which there are no vessels, but which exhibits faint traces of cellular tissue. The entire compressed vascular cylinder has a maximum diameter of about ·015. No traces of vascular bundles appear in the young leaves. The external aspect of these young leaves is represented in Plate XLV. fig. 31. Longitudinal sections of them show that the basal half of each one is turgid and thick, whilst at about half its length it suddenly contracts into a thin and semimembranous form. Advancing from this example we pass through intermediate forms to Plate XLI. fig. 1, where, as we have already seen, the leaves are fully formed, and where there is a slight tendency to differentiation between an inner bark (*g*) and an outer one (*i*). This difference in the transverse sections is scarcely capable of being described, though the eye sees at a glance that the two tissues are not exactly alike. It partly consists in a

* All these dimensions refer, it is scarcely necessary to say, to the standard of an inch.

tendency in the cells of the inner bark to arrange themselves in a line parallel with the larger axis of the section, partly in the more uniform size of the cells, and partly in the less dense character of the tissue. On turning to the central vascular bundle, we find that it has undergone a considerable change. The vessels have become much more numerous, and the transverse sections of the larger ones have a larger axis of ·0033. The vascular and somewhat compressed cylinder itself has a longer diameter of ·022, and an uncompressed circular one belonging to a twig of about the same size as Plate XLI. fig. 1 has a diameter of ·017. Fig. 4 represents a transverse section of one of these larger cylinders, drawn to the same scale as fig. 2.

Vertical sections of specimens in this stage of growth reveal yet more distinctly the changes that have occurred. Plate XLI. fig. 5 represents such a section made across the shorter diameter of an example like fig. 1; figs. 6 & 7 are the radial sections of the bark of two other similar specimens.

Plate XLI. fig. 5 reveals at *a* a slender column of very delicate cells elongated in the vertical direction; these cells are obviously those of a rudimentary medulla. At *d* are the barred vessels of the vascular cylinder; *h*, *h* is a cellular mass considerably disorganized, but of which we shall learn the true structure from other examples; at *i* is a layer of elongated cells with oblique overlapping extremities, a true prosenchyma, the cells of which occasionally become so much elongated as to approach the general condition of bast-tissue*; whilst at *i'* the prosenchymatous cells gradually become broader and shorter, thus passing into a parenchyma (figs. 6 & 7, *k*), which usually forms the exterior of the plant, but which is not well represented in the specimen, fig. 5. I think there can be no doubt that the inner parenchymatous tissue (*h*) represents the *middle* cortical layer of my previous memoir, whilst *i* represents the *outer* bark, and *k* the *epidermal* layer of the same memoir, but which latter may be more accurately termed the *subepidermal* layer. In the present instance *h* appears to be the innermost layer of the bark; but I have previously applied the term *inner* to a very delicate structure, found in some plants (e. g. *Stigmaria*), which I do not detect in the specimens under consideration. The distinctive features of the three layers of bark just described are sufficiently obvious. The cells of the layer *h* are arranged in rather regular vertical columns, each column having a diameter of about ·00022, the entire layer being about ·0025 in thickness. These cells are almost destroyed in fig. 5, but in figs. 6 & 7 their true aspect is well shown. They have square and not overlapping extremities. The longer ones are about ·0008 in length, being about three times longer than broad, but in many of them length and breadth are about equal. The prosenchymatous layer (*i*) is thicker than the more internal parenchymatous one, whilst the largest of its cells are as much as ·0025 in length, mingled, however, with numerous others of much smaller dimensions. The cells of the subepidermal or outer parenchyma (*k*) are of the ordinary character,

* The use of this term is not intended to imply that the part of the bark in which these elongated cells occur is homologous with the liber of Dicotyledonous stems, but that the individual cells are similar to those to which the liber owes some of its chief peculiarities.

exhibiting a tendency to elongation in the surfaces of the leaves (Plate XLI. fig. 5, *l*). I have had the utmost difficulty in determining whether or not vascular bundles were prolonged into the leaves of these young Lepidodendroid branches; I cannot find such in the smaller twigs, but I have detected them in two specimens rather larger than fig. 1; and in some others I trace vacant spaces in the leaves which, I doubt not, were occupied by similar bundles. In one transverse section, like fig. 1, I discover two small bundles at a little distance from the central cylinder.

Various sections in my cabinet exhibit a gradual increase in the size of all the concentric layers of tissue just described. Plate XLI. fig. 8 is a transverse section of one of the larger vascular cylinders, drawn to the same scale as figs. 3 & 4. The cylinder in this instance is nearly uncompressed, and has a diameter of ·0625, whilst the area occupied by the cellular medulla has attained to a diameter of ·03. The barred vessels composing the cylinder have also undergone a corresponding increase in their dimensions, the largest of them having attained to a maximum diameter of ·005. The expansion of the cylinder is but partly due to the increase in the size of the vessels. There has been a simultaneous increase in their number. In the three figures 3, 4, & 8, Plate XLI., every vessel in the respective sections has been copied with geometric accuracy, so that the drawings may be relied upon as correct transcripts of the sections. We find that in fig. 4 there are about eighty vessels in the entire cylinder; in fig. 8 there are more than four times that number. It will also be observed that a large number of very small vessels is developed at the periphery of the cylinder, these being apparently the newest growths of the series.

Plate XLV. figs. 31 & 32 represent the external aspect of the leaves at this stage of the plant's growth. They are ovato-lanceolate, and very closely imbricated. The central longitudinal keel is more or less prominent, as is also shown to be the case in their transverse sections. I have found a few fragments in which this dorsal ridge is impressed with several transverse indentations, as represented in fig. 32: whether this condition represents a distinct species or a mere variety I am unable to say; at all events it is not the common form of these leaves. In their general habit these twigs closely resembled the *Lycopodium Saururus* figured by BRONGNIART*. Small as these leaves are in this young state, they gradually develop into thick scale-like structures, which ultimately attain to considerable dimensions.

The next step takes us to Plate XLII. fig. 9, where we find the plant assuming the form of the young branch of a *Diploxylon*. The specimen represented is much compressed, so that the cellular medulla is obliterated, or nearly so. The two inner sides of the vascular medullary cylinder (*c*) are thus forced into close contact. The thickness of this cylinder, from its inner to its outer surface, has been about ·044, that of Plate XLI. fig. 8 having been about ·014; hence we see that this portion of the plant has here undergone a yet further increase in the number of its component vessels. But a new element now makes its appearance for the first time. The vascular medullary cylinder

* Végétaux Fossiles, tome ii. pl. i. fig. 1.

is closely invested by a second ring of barred vessels (*d*), arranged in radiating lines, and the products of an exogenous process of growth. The thickness of this exogenous vascular zone, in the specimen under consideration, is about the same as that of the medullary one which it incloses. Each radiating line commences, at its inner extremity, at one of the very small vessels corresponding with those at the periphery of Plate XLI. fig. 8. From this starting-point new vessels have been added to the peripheral end of the line, as occurs in the case of the wood-cells of coniferous plants; but here each succeeding vessel has been somewhat larger than the one preceding it, so that many of the outermost ones of this cylinder have a mean diameter of ·005. Each of the radiating rows consists of from thirteen to seventeen vessels. On making vertical sections of this specimen new elements revealed themselves. Plate XLII. fig. 10 represents a small portion of a radial section crossing the two cylinders. To distinguish these latter from each other I will now employ terms used in my previous memoir, designating the inner one the *medullary* cylinder and the outermost the *ligneous* zone. In fig. 10 part of the former is represented by *c* and the latter by *d*. The drawing shows the gradual increase of size in the vessels of the ligneous zone as we proceed from within outwards. At *d'* we find the very small vessels from amongst which the radiating exogenous series originates; and we now find that large and well-defined bundles of vessels (*m*) spring from the same series, but which curve rapidly outwards so as to proceed horizontally, and at right angles to their original course, to the periphery of the ligneous zone. These vessels are very small, not averaging more than ·0006 in diameter; but as considerable numbers of them are aggregated to form each bundle, the latter attains to conspicuous dimensions. That they are identical in character with those already noticed as observed in the young leaflets I have no doubt; but it is also obvious that the bundles have now become very much enlarged, though no corresponding enlargement has taken place in the individual vessels. This increase in the size of the bundles is explained by the fact, that whilst in the specimen represented in Plate XLI. fig. 1 the largest leaflets are not more than ·055 in diameter, in that under consideration (Plate XLII. fig. 9) they have expanded to more than double that size, or ·12. Medullary rays also now make their appearance in the ligneous zone; but as I propose to describe these more fully when speaking of the matured stem, I will not dwell upon them now. The greater part of the bark has disappeared from this specimen; all the inner parenchymatous layer is gone, and most of the prosenchymatous one. All that remains consists of the parenchymatous subepiderm with its leaf-petioles (Plate XLII. fig. 9, *l*), and with a small portion of the prosenchyma of the outer layer, *i*, attached to its inner surface. In the transverse section the cells of the latter have now begun to assume the radiating linear position which I described in my last memoir as so commonly characterizing this tissue amongst the Lepidodendroid plants.

The specimen last described has obviously been a stem or branch, with a diameter of about 1½ inch; but other examples in my cabinet lead us up from this one to stems of much larger size.

Plate XLII. fig. 11 is a transverse section of a woody cylinder of a large stem. Calculating roughly the proportions which the vascular axis of fig. 9 has borne to the entire stem, I conclude that fig. 11 represents the vascular axis of a stem of about 14 inches in diameter; its central medulla has a mean diameter of about half an inch, whilst that of the entire vascular area is nearly an inch and a half. The medulla (*a*) is present, though considerably disturbed; but sufficient remains in a normal position to show that its cells were arranged in vertical columns, a disposition which is well illustrated by another specimen in my cabinet to which I shall call attention. I pointed out in my last memoir that this disposition to a columnar arrangement of the medullary cells is a common feature amongst the Lepidodendroid plants. The medullary cylinder (*c*) is very narrow in proportion to the diameter of the stem, not averaging more than ·055. The *thickness* of the ligneous zone (*d*), on the other hand, is fully half an inch. On one side the medullary cylinder has been detached from the ligneous zone and forced inwards into the pith by some force that must have acted through one of the two extremities of the specimen, since the ligneous zone is but slightly disturbed at its inner surface, and not in the least so externally. In this specimen the large vessels of the medullary cylinder have a mean diameter of ·0075, a large increase upon the ·0025, which was the maximum diameter in the young twig, Plate XLI. fig. 2. The great thickness of the ligneous zone is due to an enormous increase in the number of vessels in each radiating line, they having increased from the 13 to 17 of Plate XLII. fig. 9 to from 84 to 100. There is not a corresponding increase in the diameter of these vessels; the more peripheral ones are actually smaller than those in the central parts of the woody zone. This may readily be accounted for. The latter have now attained to their maximum development, whilst the former, being younger, have not done so.

Plate XLII. fig. 12 represents a tangential section of a portion of this ligneous zone, magnified 10 diameters. We here see the vascular bundles (*m*) passing outwards to the leaves, arranged in regular quincuncial order. Fig. 13 exhibits a portion of fig. 12, enlarged 40 diameters: we here find that numerous medullary rays (*f*) pass outwards between the barred vessels (*e*); these rays sometimes have but from one to four or five cells in each vertical pile, but in other instances their vertical extension is considerable. The cells of the rays have disappeared, but the spaces they occupied are well marked by the deep indentations which their pressure has made upon the walls of the contiguous barred vessels. In radial sections of the stem these rays are seen proceeding towards the periphery horizontally (fig. 10, *f*), and as straight as if they had been drawn with the aid of a parallel ruler. Enough of their form can be ascertained to demonstrate that they consisted of the mural form of parenchyma. In the centre of fig. 13 we have one of the foliar vascular bundles (*m*) passing outwards through a lenticular space corresponding in all respects, save size, with a medullary ray. Like these latter appendages, the space not occupied by the vascular bundle was occupied by cells identical with those of the medullary rays; and in many instances these lenticular spaces pass into and are continuous with true medullary rays. We

shall afterwards see, from the way in which these spaces are formed, that they do not differ in any essential respect, except in their size and in the number of their cells, from such true medullary rays. The vascular bundles (*m*) are of course divided transversely in these tangential sections, in which they exhibit a diameter of from ·005 to ·0075. Each bundle consists of a large number (rarely less than 100) of minute barred vessels, varying from ·0005 to ·0008. The origin of these bundles amongst the minute vessels which abound at the point of junction of the medullary cylinder and the ligneous zone has already been shown. In the *Diploxylon* originally described by CORDA (Flora der Vorwelt, tab. x. fig. 3, and tab. ii. fig. 1) these bundles are represented as ascending obliquely upwards and outwards; but in the plant before us such is not the case; they wend their way outwards through the ligneous zone, as do also the medullary rays, in a perfectly horizontal plane. The second of CORDA'S figures also represents them as originating *abruptly* at the external surface of the medullary cylinder. Their real origin has been already shown in Plate XLII. fig. 10. CORDA further describes his plant as having no medullary rays. This, as I have pointed out in my previous memoir, is also an error, and has arisen from the circumstances there indicated, viz. that in some species of *Diploxylon* the CELLS of the medullary rays are barred, which caused CORDA to mistake them for true vessels.

In other specimens of *Diploxylon* which I possess I find some variations from that just described, as well as some points which are more fully elucidated by them. In several examples the medullary cylinder is very much thicker than in others, in proportion to the diameter of the medulla. In some its thickness is as much as ·12. One remarkably fine example exhibits the true structure of the medulla; a vertical section of the medulla and medullary cylinder of this specimen is given in Plate XLII. fig. 14. The space between the letters *a a* is occupied by the cells of the medulla, which are arranged in vertical columns with a considerable approach to regularity, when undisturbed by pressure or mineralization. These columns have a mean diameter of ·005 to ·0075. Generally the cells are nearly cubical, allowance being made for the frequent obliquity of the transverse septa, one of which sometimes inclines upwards and the other downwards at the two extremities of the same cell. Fig. 15 represents a small portion from a transverse section of the same specimen, illustrating the relations of the ends of these columns of cells to the intersected vessels of the medullary cylinder. It will be seen that the cells (*b*) can only be distinguished by their colour and their thinner walls from the vessels (*c*). The colour is due to the circumstance that one or both of the transverse cell-walls of each cell appear in the plane of the section, their carbonaceous substance giving a brown colour to the section where they exist. On the other hand, the vessels being long tubes filled with translucent carbonate of lime, transverse sections of them exhibit no such colour. The walls of the vessels also are more sharply defined and thicker, owing to the deposit of lignine forming the transverse bars in their interior; but in every other respect of size and shape the two exhibit no material differences. It is difficult to believe that the very peculiar arrangement of the cells in vertical

piles of uniform width is not a result of the same polarizing tendencies in the primitive tissues as those which led the cells of the latter to arrange themselves in a similar manner to form the barred vessels. In the latter the conversion into vessels has been completed. In the former the cells remained unconverted; but they have not only retained the primary disposition to assume the columnar form, but the same tendency reappears in all the new cells subsequently formed in the enlarging pith.

Whilst the large specimens last described are almost invariably accompanied by some portion of their bark, which surrounds them as a flattened cylinder, I have in no one such instance obtained so perfect examples of this bark as in the specimen represented by Plate XLI. fig. 1; the tissue is usually limited to its outermost part, viz. to the subepidermal parenchyma and a small portion of the subjacent prosenchyma. The example Plate XLII. fig. 11 was so surrounded, a small portion of the bark being seen at *i*. Fig. 15[a] represents a vertical section of a fragment of bark from the same specimen; to the left of the figure we have the two tissues (*i* and *k*) just referred to, whilst at *l* are the persistent bases of the petioles, which remain *in situ* in this plant, as in CORDA's genus *Lomatophloios*. In this figure, which represents the object of its natural size, the leaf-petioles are small, though larger than in the bark of fig. 9; but I have specimens in which they are fully three times the size shown in fig. 11. Thus it will be seen that I have these leaves in every gradation of size, from the imperfectly formed one of Plate XLI. fig. 2, to large ones which, though their extremities have been broken off, have their basal petioles five eighths of an inch in length. But though large stems rarely have the bark *in situ* and in perfect condition, Mr. GRIEVE has sent me several large masses of it, so that it does not appear to be a scarce object. But it usually occurs in a remarkable state, being deeply fissured longitudinally, and partially broken up into long wedge-shaped masses, linked together at their broad bases—a probable result of desiccation.

In the transverse section, that which appears to be identical with the inner parenchymatous bark (*h*) of the young twigs merely appears as an ordinary form of parenchyma; its usual aspect in radial sections is shown in Plate XLIII. fig. 16; it consists of innumerable square cells, slightly elongated vertically, and exhibiting some disposition towards an arrangement in perpendicular lines, reminding us of what is seen in Plate XLI. figs. 6 & 7, *h*. The prosenchymatous layer is easily identified with the layer *i* in the two figures just referred to. It is very thick, and the cells vary in form, being sometimes much larger, as well as more fusiform, than at others; whilst towards the exterior of the layer radial sections exhibit in a very marked manner the arrangement of prismatic cells seen in Plate XLIII. fig. 17. These cells are elongated vertically in a very regular manner, having a uniform diameter from end to end of about ·0025. Their length varies greatly: sometimes, though not often, they are almost square; at others they are so much elongated, especially at the outer portion of the layer, that they almost assume the form of vessels; but what gives them their remarkable appearance is the fact that clusters of them have exactly the same length, and are arranged in the same radial plane, causing

numerous straight lines of transverse cell-walls to traverse the section horizontally from within outwards, as shown in Plate XLIII. fig. 17, *i*. There is no doubt that the walls of the more tubular of these elongated cells are thickened by internal depositions of lignine, and that they thus assume the character of bast-tissues. I have already described thin-walled cells arranged in regular rows which, in outward form, closely resemble those of Plate XLIII. fig. 17, but occurring in the primary and secondary medullary rays of Calamites. The tissue is a very peculiar one. I have not succeeded in discovering any structure absolutely identical with it elsewhere than amongst these Carboniferous plants. I have already referred, both in my preceding memoir (Part II.) and in the present one, to the fact that transverse sections of this prosenchymatous layer of the bark exhibit the cells arranged in regular radiating lines proceeding from within outward, as in the wood of the Coniferæ. On seeing such sections, it is difficult to resist the impression that we are looking at true vascular tissues.

The subepidermal layer differs in no material respect from that of the young twigs, being composed of ordinary parenchyma. The same remark applies to the structure of the persistent petioles, except that in transverse sections of the latter we find the position of the central vascular bundle very distinctly marked, as in the scars of the ordinary *Lepidodendra*. It will be remembered that this was not the case with the leaflets of the smallest twigs. Plate XLIII. fig. 18 represents part of a tangential section of a cluster of these petioles made close to the subepidermal layer of bark. In their disposition and general aspect they remind us vividly of a similar section of CORDA's *Lomatophloios crassicaule*, figured by him in his 'Flora der Vorwelt'*.

Having thus completed our review of the ordinary structure of these stems, I would next direct attention to some peculiarities connected with their growth.

In preparing my sections, on one or two occasions I met with small, detached, medullary cylinders corresponding in all respects with those of the young twigs, only instead of being perfect rings of vessels, they were interrupted on one side, giving the transverse section of each the form of a horseshoe. I was long before I succeeded in discovering what this meant. It was obviously a medullary cylinder, and I at length obtained specimens which explained its nature. When one of the stems is about to dichotomize, the central vascular cylinder first becomes elongated laterally in the plane of the approaching bifurcation; it then splits into two halves, each of which is, of course, open at its inner side. Plate XLIII. fig. 19 represents the centre of one of these specimens, belonging to a twig of about the same size as Plate XLI. fig. 1. What takes place subsequently is uncertain; but there is reason to believe that the opening thus made into the interior of the medullary cylinder, bringing the medullary and cortical tissues into direct contact, never closes through any growth of new *medullary* vessels. I am confirmed in this opinion by the fine section shown in Plate XLIII. fig. 20, which reveals similar conditions, only in this example the plant has attained to the *Diploxylon* stage of growth, having developed an ample exogenous cylinder externally to the medul-

* Taf. 1. fig. 1.

lary one. In the minute details of its structure this plant differs in no respect from those already described. But we here see that whilst nature has made no attempt to reclose the vascular cylinder (*c*) and again separate the pith (*a*) from the bark by means of the medullary vessels, she has endeavoured to accomplish the same process, though not yet effectually, through the instrumentality of the exogenous ligneous zone (*d*). In each of the divisions this exogenous zone overlaps the two free central margins of the medullary one, thus gradually filling up the gap between them. I doubt not that eventually such a closure of the vascular ring and isolation of the medullary area would become complete. I presume, from the comparative rarity of specimens with these open vascular cylinders, that after a growing branch had bifurcated, the buds of the two growing twigs have developed their medullary cylinders in the usual way, and that the imperfection of the cylindrical ring is confined to the neighbourhood of point of dichotomization. I have not met with an open ring in a single branch, save when it had obviously been ruptured by violence. The specimen (Plate XLIII. fig. 20) is enclosed within the usual cylinder of bark (*i*).

The last subject brings us to another one on which my views have been criticised by some botanists for whose attainments I have the greatest respect, but who have not had the advantage of being able to study the large series of specimens which my cabinet contains. In both my previous memoirs I expressed my conviction that both in Calamites and in the Lepidodendroid plants the peculiarities of their structure could only be explained by the recognition of an exogenous mode of growth by which these peculiar features had been produced*. My more recent researches have still further strengthened these convictions; so much so, indeed, as not to leave a shadow of a doubt on my own mind as to the correctness of my conclusions on this subject. The specimens represented in Plate XLIII. fig. 20 and Plate XLII. fig. 11, especially the former of the two, afford striking illustrations of this process of growth. The cylinder in the upper half of the former figure exhibits no unusual peculiarity; but the lower one is surrounded by a remarkable zone of half-developed vessels (*d'*), which is evidently of newer formation than the rest of the ligneous zone, and which I can only explain by the assumption that it is the product of some equivalent of a cambium-layer. Plate XLIII. fig. 21 represents a portion of the exterior of the ligneous zone (*d*), with its radiating lines of vessels (*e*) separated by medullary rays (*f*). Externally to these tissues, we have at *c'* a new zone

* My views upon this question having excited so strong an opposition in some quarters, I invited Professor DICKSON, of Glasgow, to visit me for the purpose of examining my specimens and giving me his opinion of them. He kindly authorizes me to publish the following significant extract from a letter just received from him, dated March 17, 1872:—"Having examined your sections of stems of *Diploxylon* showing the outermost woody tubes to be of distinctly smaller calibre than the more internal ones, as well as sections of a series of stems of the same, from small to large, affording constructive evidence of a progressive increase of the wedge-like woody plates, I have no hesitation in expressing my belief in a truly exogenous growth in this plant; and I consider that you are quite justified in applying the terms 'medulla,' 'woody zone,' 'medullary rays,' and 'bark' to its parts, as corresponding more or less perfectly to analogous parts in the Dicotyledonous stem."—March 19, 1872.

in process of development; it consists of numerous masses of small vessels arranged, in the transverse section, in a radiating direction, but of which the lines have not yet assumed the orderly disposition that characterizes them when fully developed. Between these vascular laminæ are cellular masses (f'), the positions and structure of which obviously show that they are destined to become prolongations of the medullary rays (f). Plate XLIII. fig. 22 represents part of a tangential section of the new tissue (fig. 21, e', f'), which is very instructive. The right-hand portion of the section dips more deeply into the specimen than that to the left; the latter consequently exhibits the more peripheral aspect of the structure. In the former the vessels are becoming closely arranged, and the medullary rays (f'), though still much more enlarged and containing more cells than characterize the matured rays of the woody zone, are comparatively circumscribed; but in the more peripheral part the vessels (e'') are more widely separated, meandering through large cellular masses (f''), which are scarcely, if at all, distinguishable from the contiguous parenchymatous bark-cells. These young vessels have a diameter of from ·0025 to ·0012, whilst the transverse bars on their walls are from ·0003 to ·0002 apart. In the matured vessels we have a diameter of from ·005 to ·0024, whilst the bars are from ·0008 to ·00035 apart. The comparison of these figures demonstrates that the young vessels under consideration are but half-developed in either direction; both in their diameter and in the longitudinal separation of their bars of lignine they must have attained to double their present dimensions before they corresponded with those of the matured ligneous cylinder which they invest. At this early stage of their growth the walls of these vessels exhibit a crenulated outline, the indentations being caused by the pressure of the contiguous cells upon the half-plastic tissues. This feature disappears as the vessels swell to their full dimensions and are brought into mutual contact by the absorption of the cells which temporarily separate them; but it is permanently maintained where the vessels are in contact with the medullary rays. I have not been able to identify any of the cellular structures that surround them with true cambium-cells: though exceedingly delicate they have the aspect of *formed* tissues; but there is not the slightest room for doubting that both cells and vessels are younger than those of the ligneous zone which they enclose, or that they are the products of an exogenous growth in which the *Xylem* of the German botanists is represented, whilst the *Phlöem* is absent*.

I have called attention to the break in the continuity of the medullary cylinders of Plate XLIII. fig. 20, through which a direct communication is established between the cells of the medulla and those of the bark. The equivalent of the cambium has bent round the two inner horns of the crescent-shaped medullary cylinder and formed the

* I may observe here that since my last memoir was written I have obtained specimens of *Stigmaria* which exhibit conditions very similar to those of the example of *Diploxylon* just described, but in which the growth of the new vessels is rather more advanced. I have noticed that in *Stigmaria* the additional growths are rarely made in complete circles, but rather in layers having crescentic transverse sections; I have found the same conditions in some other plants from the Coal-measures yet to be described.

new vessels in the open space between them, thus obviously being instrumental in repairing the breach in the continuity of the cylinder and closing it up by a succession of exogenous additions. It has not completely effected this object in the specimen under consideration, but apparently would have done so in the course of time had the plant survived sufficiently long for the purpose. Another remarkable circumstance appears in the fact that the two ligneous axes, though growing within the same stem, are not growing in equal ratios. Thus that to the lower part of Plate XLIII. fig. 20 is invested by the new layer just described, showing that in it an additional growth was progressing through the agency of some representative of a cambium-layer; but in the twin axis above no such addition is in progress. I presume we can only infer from this fact that at the particular moment when the living plant was destroyed the former branch was pushing forward in a more active manner than the latter one—a condition common enough amongst recent plants, in which one Lycopodiaceous shoot takes the lead, whilst others are comparatively quiescent.

At the outset of my study of the Burntisland beds my attention was arrested by the prevalence, *in every fragment* of the stratum, of broken-up cellular sporangia, indicating the former existence of very numerous spore-bearing fruits; I also met with immense numbers of the remarkable bodies represented in Plate XLIV. fig. 27, and which appeared to me to be caudate macropores. The abundance of these two objects led me, on visting Burntisland, under the guidance of Mr. GRIEVE, to make special search for *Lepidostrobi*, which we soon succeeded in discovering, and at a more recent period Mr. GRIEVE has forwarded me additional specimens. They are all of one species, which fact is important, since it leaves little, if any, room for doubting that they belong to the same Lepidodendroid plant as that whose stems and branches constitute the great mass of the deposit.

The general aspect of longitudinal sections of these strobili is that common to *Lepidostrobi*. They usually have a diameter of from less than half an inch to nearly an inch; each sporangium extends from the central axis to the periphery, exhibiting in the longitudinal sections the form, so prevalent amongst these fruits, of an oblong parallelogram. In one of these sections now before me I count sixteen vertically disposed sporangia in an inch of the length of the *Lepidostrobus*. These dimensions approximate closely to those of the beautiful cone from Burdiehouse figured by Mr. BINNEY*. Plate XLIV. fig. 23 represents a transverse section of one of these cones. The central axis (s) in this specimen is imperfect, its central vascular bundles having partly disappeared; but there remains a thick and well-defined cortical layer composed of elongated forms of parenchyma approaching the prosenchymatous type, and identical with what we find in the external portions of some of the Lepidodendroid leaves. From this central axis are given off thick and robust cylindrical scales or bracts (t), consisting of a similar tissue to that of the cortex; they spring from the central axis in the usual spiral order common amongst the

* "Observations on the Structure of Fossil Plants found in the Carboniferous Strata.—Part 2. *Lepidostrobus* and some allied Cones," by E. W. BINNEY, F.R.S., F.G.S. (Palæontographical Society, 1871), pl. x. fig. 26.

Lycopodiaceæ, having a thickness at their respective bases of about ·022; but they soon subdivide into smaller branches, which generally proceed to different sporangia. Though the latter are very much more numerous than the primary bracts, each sporangium rests upon its own special branch of a bract. The sporangia (*u*) exhibit in this section a wedge shape. The small peripheral sporangia (*u'*) seen in the figure are merely the tips of the next contiguous ones rising up from below, in consequence of their slightly oblique and ascending plane not corresponding with the horizontal one of the section. Plate XLIV. fig. 24 is a tangential section of another specimen, which exhibits the oblique spiral arrangement of the sporangia characterizing the taxis of these fruits. At *t* we have the free extremities of the subdivided bracts. Fig. 25 represents a small portion of fig. 24 more highly magnified, and exhibits with remarkable clearness the shape of the subdivided bracts, and the way in which the latter are attached to their respective sporangia. The perfect sporangium (*u*) occupying the centre of this figure may be accepted as a type of the structure of these organs and of their relations to the bracts. Each sporangium is enclosed in a cellular sporangium-wall (*v*), which, when viewed superficially, appears composed of ordinary parenchyma, but when seen in section exhibits these cells elongated vertically, the structure closely resembling a corresponding section of a piece of honeycomb. Sometimes one cell extends from surface to surface, at others two cells of equal diameters are piled linearly upon each other. The average thickness of these sporangium-walls is ·0075. The shape of the transverse sections of the secondary bracts is shown in the three dark-coloured objects (fig. 25, *t*), especially in that supporting the central sporangium. The upper surface is rounded and prominent, fitting into a corresponding depression in the under surface of the sporangium. On each side of this the bract spreads out into a thin horizontal expansion, concave superiorly; at its inferior surface a deep thin keel runs along the entire length of the bract and dips down between the two contiguous sporangia of the series immediately below, as if designed to steady the several segments of the strobilus. From the interior of the raised dorsal surface a similar but smaller and thinner vertical lamina rises, the upper part of which ascends into the sporangium and is imbedded amongst the spores; its uppermost margin is bifid, the two diverging parts being recurved in opposite directions outwards and downwards. This ascending portion, obviously the true sporangiophore, is of so delicate a texture, especially at its upper part, that it can only be distinguished from the surrounding spores by its denser aspect. The delicate lines *t'* in fig. 23, which appear as continuations of the large bracts, are longitudinal prolongations of the same sporangiophores, which appear to be coextensive with the entire length of the sporangium. The sporangium-wall is inserted into the bract close to the base and at each side of the sporangiophore. It first arches upwards as it approaches the latter organ, and then, suddenly descending, it plunges vertically into the bract, with the parenchyma of which its own cells become intermingled. It thus appears that each sporangium is not only sustained by its own bract, but is united to that bract throughout its entire length in the firmest manner. I have not been able to ascertain the actual forms of the peripheral extremities

of the bracts. In every instance they have been too much disorganized to display their true contours; but both figures 23 & 24, Plate XLIV., show that they are prolonged so as to form a thin investment to the exterior of the strobilus.

The sporangia of the upper part of this fruit are densely filled with innumerable microspores, whose mean diameter is about ·0007. Sometimes they are tetrapartite (Plate XLV. fig. 26, *w*), and at others tripartite (fig. 26, *w'*). In the lower part of the strobilus the sporangia are occupied by the remarkable macrospores represented in Plate XLIV. fig. 27, *x**. These vary considerably in their form, owing to pressure or shrivelling; but they appear to have been more or less spherical. The one figured, the length of which exceeds its breadth, has a longer diameter of about ·027; and from this to ·05 appears to have been nearly the average size of these objects. The characteristic peculiarity of these macrospores is the projection from every part of their external surfaces of numerous caudate appendages, and which appear to be actual prolongations of the investing layer of the spore. These appendages vary in length from ·003 to ·0055, whilst their diameter is about ·0006. They are rather thicker at their bases than nearer their extremities; but the extreme tip of each one is slightly capitate. They have evidently been very flexible, since they are twisted into varied positions. I detect in them nothing resembling elaters, their texture, like that of the external spore-wall, being perfectly homogeneous. When the strobilus is viewed either by transmitted or by reflected light, all the spores, whether large or small, appear of a rich brown colour, a condition which has been noticed by Mr. BINNEY and Professor MORRIS as characterizing certain spores which have come under their observation†. I have not succeeded in discovering any structure in the interior of these objects. I have only obtained these macrospores in actual connexion with two strobili. In one they occupy the lower part of the fruit as already described, four sporangia of which fruit are represented in Plate XLIV. fig. 28. It will be seen from the latter figure that most of these spores (*x*) are torn and distorted. In another fruit the numerous shrivelled sporangia remain; but they have all shed their macrospores, with the exception of three, the spores of which closely resemble those shown in fig. 28. In all these examples the rich brown colour resides in the spore-wall, and not in its contents, whatever those may have been.

That we have in this fruit a new example of that remarkable class of fossil strobili to which attention was first called by ROBERT BROWN and Professor BRONGNIART is obvious; and I think the reasons I have already given justify me in connecting it with the stems and branches with which I find it associated. No plant of the Lepidodendroid family occurs in the deposit other than those which I have described, save one or two small fragments of a Lepidodendroid bark of the ordinary type, and which very possibly belong to the lowermost parts of the stems now described. In many recent Cycads we find that, immediately below the cluster of perfect leaves, we have a considerable part of the stem

* In this figure the macrospore (*x*) and the microspores (*w*) are drawn to the same scale, showing their relative sizes.

† BINNEY'S "Observations on the Structure of Fossil Plants, &c.," part ii. pp. 44 & 45.

retaining the bases of the petioles after the fronds have fallen; whilst yet lower down on the stem these petioles have disappeared, revealing characteristic lozenge-shaped scars, rendered visible less by the disarticulation of the petioles than by a process of weathering which has disintegrated them down to the level of the cortical layer. It appears to me exceedingly possible that similar phenomena may have occurred in the case of the plants under consideration. In the few fragments of true Lepidodendroid scars which I have met with these scars are long and narrow, corresponding very closely with what I observe on some of the smaller twigs described, from which the leaves have become accidentally detached. These circumstances combine to remove all doubt as to the relationship subsisting between the stems and branches described in the earlier part of this memoir and the strobilus last considered: either as fragments of sporangia and detached spores on the one hand, or as leaves and portions of stems and branches on the other, the two classes of vegetative and reproductive organs are represented in every square inch of the rock I have examined; and as every strobilus which I have obtained is of one species, and that one identical with the innumerable distinctive macrospores referred to, it appears to me that we have every proof of their identity that palæontology can furnish, unless we could discover the tree in its integrity, which is impossible.

I have stated that the central axes of these strobili are commonly imperfect. In one of them we have the usual central bundle of barred vessels partly preserved; but I have obtained one larger specimen, represented in Plate XLIV. figs. 29 & 30, which I think may possibly belong to the same fruit. If so, it has been part of the base of the axis of a somewhat larger strobilus than those described. Fig. 29 represents a transverse section of it, in which is seen a central star-shaped cluster of barred vessels (*s*), surrounded by a vacant space from which delicate cellular tissue, corresponding with the inner or middle bark of the Lepidodendroid twigs, has doubtless disappeared. External to this is a thick cortical layer of parenchymatous and prosenchymatous tissue, the peripheral portion of which has broken up into thick divergent bracts, each of which has again divided into secondary ones, as described in the preceding pages. This divergence is demonstrated by the subdivisions of the vascular bundles seen at t', t'. On turning to the longitudinal section (fig. 30) we see that the vascular bundles of the bracts have, as was to be expected, sprung from the central axis (*s*) at s', and after traversing the clear area (*g*) have proceeded upwards and outwards through the thick cortex, as shown by the numerous vacant spaces (*m*) from which the vessels have disappeared. Peripherally the bark breaks up into main or primary bracts, which again subdivide, as in the transverse section, into secondary ones, demonstrating that each primary bract does not merely dichotomize but subdivides, both horizontally and vertically, into a cluster of bracts—a condition corresponding with what I have already observed in the smaller strobili described. The external surface of the central vascular axis (*s*) has evidently been deeply sulcated longitudinally, the vascular bundles having sprung from the intermediate ridges. In the transverse section the vessels of the outermost portions of these ridges exhibit a radiating arrangement, as if the axis had made a

slight effort to strengthen its buttresses by exogenous additions to their exteriors. In tangential sections of the cortical layer the vascular bundles exhibit the regular arrangement characterizing the taxis of all Lepidodendroid stems.

Before attempting to draw any general conclusions from the preceding facts, I would call attention to two interesting modifications of the same Lepidodendroid type that have recently come under my notice. One of these, represented in Plate XLV. figs. 33 & 34, I found in one of the Oldham nodules; the other is in the cabinet of Mr. NIELD, of Oldham.

Plate XLV. fig. 33 represents a transverse section of the first of these plants; it is a young Lepidodendroid shoot a little more advanced in growth than Plate XLI. fig. 1; in other respects the general appearances of the two closely correspond. The chief difference lies in the centre of the medullary axis, which in Plate XLV. fig. 33 is very large and well defined. On turning to the longitudinal section of the medullary cylinder (fig. 34) we see that this medulla (*a*) is a cellular structure; but instead of the cells being nearly cubical, they are elongated vertically and almost fusiform; still they retain much of the disposition to arrange themselves in vertical columns that is so common a feature of the Lepidodendroid plants. Mr. NIELD's plant, represented in fig. 35, is a very different one; its central axis is of the usual type, consisting of a medullary vascular cylinder (*c*) enclosing a cellular medulla; but whilst the latter is very small, approximating to the condition of Plate XLI. fig. 4, the former is comparatively large, being composed of very numerous vessels of nearly uniform size. The most remarkable feature of the plant is seen in the large size of the bases of the leaves (*l*), which must have approximated in form to thick scales. They are composed of the usual slightly elongated parenchyma. Unfortunately the importance of this remarkable specimen was not appreciated when it was found, and I have seen no vertical section that was made from it; hence I am ignorant of the shape which the leaves assumed in a vertical direction. The maximum diameter of the transverse section is nearly three quarters of an inch*.

* It appears that Mr. BUTTERWORTH prepared other sections of the above specimen, which he recently sold, through Mr. CARRUTHERS, to the Trustees of the British Museum. Mr. CARRUTHERS has described these specimens in a paper which he read before the Royal Microscopic Society since the above descriptions were penned. In this paper he describes the vascular medullary cylinder, but does not refer to the vacant space in the centre of his own figure, which I believe was originally occupied by medullary cellular tissue. I think that the section which I have represented in Plate XLV. fig. 35 displays indications of this cellular medulla. Speaking of the *vascular* cylinder, Mr. CARRUTHERS says, "Professor WILLIAMSON, in his recent investigations into the organization of *Lepidodendron*, proposes to call this axis a medulla." This is certainly not an exact representation of the idea put forth in my last paper; I spoke of the vessels in the centre of *Lepidodendron selaginoides, where they are intermingled with cellular tissue*, as belonging to a *medullary axis* in contradistinction to the exogenous ring which enclosed them, and I then proceeded to show how, in other species, these vessels receded from the centre to the periphery of that medullary axis, where they formed in every Lepidodendroid plant, except *L. selaginoides*, a distinct cylinder, and which I described not *as a medulla*, but as being homologous with *the medullary sheath* of the higher Exogens, which is a very different thing. The true medulla is the cellular element. All my subsequent researches have tended to confirm these views. I never doubted for a moment that these axial vessels represented the vascular bundles of living Lycopods.

If I have correctly interpreted the facts just described, and I believe I have done so, the life-history of this plant throws an important light upon many of those described in the last, or second, of this series of memoirs. How far the numerous plants there referred to may prove to be different states of a few species is not easy to determine, because we do not obtain them in that condition of stratigraphical isolation which has afforded such an important help in the case of the Burntisland examples. In that memoir I pointed out how closely some of the Lepidodendroid forms resembled CORDA's *Diploxylon*, and how the absorption of the cellular medulla of some of them would actually convert them into examples of the latter genus. It is necessary to remember that hitherto none of the authors who have written on *Diploxylon* have seen either its pith or its bark. The last description of *Diploxylon* published, so far as I am aware, with the exception of my own memoir, was that by Mr. BINNEY, who says of his specimen, "although it shows the so-called medullary sheath in a very perfect state, there is nothing to indicate the former existence of a pith of cellular tissue"*; and he adds, "the part which remains undisturbed shows that the whole of the central axis was formerly composed of hexagonal vessels arranged without order:" "this view is confirmed by another and more perfect specimen of *Anabathra* in my cabinet, and enables me to speak with positive certainty, and to show that these plants had a similar structure in the central axes to the specimens of *Sigillaria vascularis* described by me in my paper published in the Quarterly Journal of the Geological Society"†.

Considering the imperfection of the materials at his disposal, no more discriminating account of these plants has been published than is contained in Professor KING's memoir entitled "Contributions towards establishing the general characters of the genus *Sigillaria*"‡. In this memoir the author examines carefully the *Anabathra* of WITHAM, which is a true *Diploxylon*, and concludes that it is undoubtedly a Dicotyledonous plant; but notwithstanding this mistake he correctly points out some of the features in which the genus approximates *Lepidodendron*, quoting BRONGNIART's suggestion as to the possibility of *Diploxylon* being the stem and *Lepidodendron* the branches of the same type of tree. With equal accuracy Professor KING insists upon the truth, recently challenged by some of our younger botanists, that the vascular medullary cylinder and the exogenous ligneous zone are independent systems.

In my previous memoir I also called attention to some of the observations of BRONGNIART and CORDA on *Diploxylon*, especially to an error into which the latter writer fell when he determined that no medullary rays existed in this genus. At the same time I explained the source of CORDA's mistake, viz. his ignorance of the fact that the medullary rays of these plants *sometimes* consist of scalariform cells, but which he mistook for vessels§. BRONGNIART has made this supposed absence of medullary rays (which he only

* "On some Lower-Coal-seam Fossil Plants," Philosophical Transactions, 1865, p. 584.

† *Loc. cit.* p. 584.

‡ Edinburgh New Philosophical Journal, No. 71.

§ It is an interesting circumstance that I have recently obtained from the Oldham Coal-measures a *Stigma-*

accepts on CORDA'S authority) one of his distinctions between *Diploxylon* and *Sigillaria*; but this distinction must now be abandoned as non-existent. WITHAM had described the large openings represented in my figures 12 & 13, *m*, Plate XLII. of the present memoir as medullary rays. Professor KING, on the other hand, correctly discerned that these openings transmitted foliar bundles, also recording his conviction that the vacant spaces surrounding the bundles had probably contained cellular tissue, which I have now proved to be the case.

But, relying upon LINDLEY'S declaration that no vascular tissue was ever found in a medullary ray, he denied the correctness of WITHAM'S application of the term to the spaces in question. Mr. BINNEY, referring to this subject, does not speak very definitely. He says that his specimen "distinctly confirms WITHAM'S opinion as to the occurrence of medullary rays *or bundles* dividing the woody cylinder"*; but he does not define what he means by bundles. At p. 600 of the same memoir he again speaks of "medullary rays or bundles of barred vessels," from which I infer that bundles *of vessels* are also referred to in the previous sentence. So far as I can ascertain, none of those observers who preceded me have distinctly recognized the true secondary medullary rays described both in this memoir and in the preceding one.

BRONGNIART, CORDA, and KING agree in considering the Diploxylons to be Gymnospermous Exogens, associating them in that great group with the true Sigillariæ.

I think the facts now published finally settle this primary question. It being admitted by all authors that the *Lepidodendra* are Cryptogams, the Diploxylons can no longer be regarded by any one as Gymnospermous Exogens; and as the close identity of BRONGNIART'S *Sigillaria elegans* with *Diploxylon* is equally obvious, we must accept the entire group as Lycopodiaceous. Dr. DAWSON, in his recent memoir on *Sigillaria*†, arrives at a different conclusion; but whatever may be the case with Transatlantic specimens, there is not the slightest room for doubt about our European ones: they are all modifications of the Lepidodendroid type. The distinction drawn by BRONGNIART between the *Sigillariæ* which have medullary rays and the *Lepidodendra* which have not, I have now shown to be merely due to difference of age. In its young state the Burntisland *Diploxylon* is an ordinary form of *Lepidodendron*. As it develops it passes through successive stages of growth, all of which appear to be more or less permanently represented amongst other matured *Lepidodendra*, though within what limits has yet to be ascertained, since, as I have already suggested, some of the forms described in my last memoir may be parts of the same plant at different ages, though in several of the examples there described this is certainly not the case. Long before attaining to the dimensions and stage of growth in

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ria, identical in every other respect with *S. ficoides*, but in which the medullary rays are similarly composed of scalariform cells. Remembering the fact that a *Diploxylon* from the same locality, which I described under CORDA'S name of *D. cycadeoides*, possessed the same features, the question arises, how far may these similarly constructed plants have borne the mutual relations of root and stem?

* *Loc. cit.* p. 583.

† Quarterly Journal of the Geological Society, May 1871.

which it becomes a true *Diploxylon*, this plant possesses a well-defined *cellular* pith. Its central axis is *not* composed of bundles of vessels, but of vertical piles of true cells. As soon as the outer ligneous cylinder makes its appearance, true medullary rays also present themselves. Simultaneous with the formation of these true medullary rays is that of my primary rays, or cellular spaces through which the vascular foliar bundles pass outwards through the ligneous zone, and which differ from the others in no respect, either of structure or of origin, save in the circumstances that they are larger and that the foliar bundles are lodged within them. The specimen from which Plate XLIII. fig. 22 is taken clearly proves this. The vascular bundles proceeding from the interior of the ligneous zone to the leaves, when once formed, evidently became permanent structures, undergoing neither increase nor diminution of number; but as the diameter of the stem steadily increased, these bundles obviously became lengthened, by some process as yet unascertained, so as to accommodate themselves to the altered dimensions of the tree, especially of its bark. It follows that when the pseudo-cambium-layer commenced its work of producing new vessels, which were added exogenously to the exterior of the preexisting vascular cylinder, it was penetrated by these leaf-bundles, and the arrangement of the newly formed vessels was modified by their preexistence. On studying these tissues in the original of Plate XLIII. fig. 22, where the arrangements of the new growths are very distinct, no essential difference can be observed between those intervascular areas filled with cells through which a vascular bundle passes, and which are destined to become what I have designated *primary* medullary rays, and those which ultimately assume smaller dimensions and become *secondary* ones. It appears to me that as the new, longitudinally arranged vessels of the young growth increased in size, the intermediate cellular tissue seen in Plate XLIII. fig. 22 was gradually absorbed to make room for them. In the secondary medullary rays this absorption was carried so far, in consequence of the pressure occasioned by the steady growth of the vessels, that nearly all the cells disappeared; whereas in the primary rays, where a vascular foliar bundle interposed between two adjacent enlarging vessels, the bundle resisted their pressure, protecting the cells immediately above and below it from its effects. Hence a lenticular space was left permanently occupied by unabsorbed cells; but at the upper and lower angles of this space it contracts to the dimensions of the true secondary medullary rays. If this explanation is correct, it establishes my conclusion that these large spaces, seen in Plate XLII. figs. 12 & 13, *m*, are but modified medullary rays, and that they are so modified, not for the purpose of transmitting the vascular foliar bundles, but as an effect of their presence, which is a very different thing.

In my last memoir I called attention to the fact that the foliar bundles originated from the line of junction between the vascular medullary cylinder and the ligneous zone*.

* I have to correct an error into which I fell on this point in the text of my previous memoir. I had clearly ascertained that the foliar bundles sprang from small vessels occupying the plane where the outer surface of the vascular medullary cylinder and the inner one of the ligneous zone were in contact, and I came to the conclusion that they belonged to the latter rather than to the former; but I now see that this was a mistake. I

This statement is confirmed by my more recent researches, as is also another observation made in the same memoir, viz. that the *crenulated* outline described by BRONGNIART and BINNEY as characterizing the line of junction between the vascular medullary cylinder and ligneous zones of *Sigillaria* and *Diploxylon* is not a constant feature in the latter genus. In the variety which I described under the name of *Diploxylon cycadeoideum*, believing it to be identical with CORDA's plant so named, I pointed out, as already stated, that the cells of the medullary rays had a barred or scalariform structure; and I showed how these cells started from an interrupted layer of similar ones located between the inner and outer vascular cylinders. Nothing of the latter kind exists in the plant now described. The cells of the medullary rays have very thin and delicate walls, differing but little, save in form, from those of the innermost bark, with which latter those of the outermost extremities of the medullary rays become actually merged. The exogenous growth of the ligneous zone which I have so long recognized, but which has been objected to by some botanists, is now more clearly demonstrated than before. Decided as were my previous convictions on this point, they have received fresh strength, so that I am less than ever inclined to abandon them. We have in these plants the three distinct tissues of pith, wood, and bark, in addition to the vascular medullary cylinder, which latter I am still inclined to suspect may typically represent the medullary sheath of the true Exogens. The specimens described in the memoir demonstrate two facts bearing upon the question of the growth of these plants:—1st, that the formative layer, whether we designate it cambium or give it some other name, has been substantially parallel with the exterior of the previously formed vascular tissues; 2nd, that this layer has displayed an intermittent activity, periodic resumptions of vigorous growth alternating with times of rest. The facts detailed in the memoir clearly demonstrate that the ligneous zone was gradually built up by a succession of such growths. The pith, primarily small, ultimately attained to considerable dimensions through the fissiparous multiplication of its cells. Possibly it may have been the pressure occasioned by this multiplication that caused the continued expansion of the medullary cylinder.

But before attempting to discuss either the physiological questions suggested by this inquiry, or the homologous relations of the various tissues of the *Lepidodendra* to those of the living Lycopods, it will be necessary to call attention to a few features in the latter objects which require to be considered.

Considerable variations exist in the structure of the living *Lycopodia* and *Selaginellæ* but an essential unity pervades the entire group. If we take a matured stem of a *Selaginella Martensii* as a simple type, we find in the centre a single large fibro-vascular bundle. In the transverse section this bundle is elliptical, consisting of a central line of vessels which are scalariform, spiral, and annular, all the three modifications occurring

fell into it from the circumstance that the small size of these vessels was in exact correspondence with that of the innermost series of the exogenous growth, and very different from that of the large vessels constituting the bulk of the medullary cylinders. Having now traced the origin of this vascular cylinder, the question appears to be set at rest.

in the group. This cluster is surrounded by a ring of very small woody fibres, the *Phlöem* of the German botanists, the innermost cells being the smallest and the outer ones the largest in the series. Around this central bundle is a cylindrical air-cavity traversed by numerous detached columns of cells, which ascend as they pass inwards from the cortical layer to the fibro-vascular bundle, to which latter they serve as a series of flying buttresses, sustaining it in its position. Externally to this air-cylinder is the bark, which varies in its composition in different Lycopods. In *Selaginella Martensii*, *denticulata*, and *Wallichii* the inner part of the bark consists of a dense mass of parenchyma, with large cells and thin transparent walls, and with a few large chlorophyl-grains in each cell. Yet more externally this parenchyma gradually passes into a thin-walled fusiform prosenchyma, the walls of the cells becoming thicker as we proceed outwards, until at their external surfaces they present a woody structure, forming the outermost envelope of the stem. But on turning to the leaves we find something more: the substance of each leaf is parenchymatous, besides which it has a true epidermal layer of sinuous cells and stomata on its under surface*.

In *Lycopodium chamæcyparissus*, though the central fibro-vascular mass is more complex than that just described, it is, as SACHS justly points out, essentially the same; but the air-cylinder of the *Selaginellæ* is absent, as is also the inner parenchyma of the bark. The prosenchymatous layer is very thick, and closely embraces the fibro-vascular bundle; its component cells also are much more thickened by ligneous deposits in their interiors than in *S. Martensii*. Another important difference exists in the fact that the parenchyma of the leaves now extends itself over the entire stem, forming an outer cortical layer; but this is not invested by any true epidermis, such as is seen covering the leaves.

If we turn from these general features to some special points in the development of these plants, we shall find that new light is thrown upon the fossil forms. The young growing bud at the tip of a Lycopod is composed externally of ordinary parenchyma; but in its interior we find formed at the earliest period a central column of what SACHS designates *procambium*, a solid cylinder of very delicate, vertically elongated cells, the transverse section of which has in most species an elliptical outline. I have carefully traced the development of these procambial tissues in many Lycopods, and can thoroughly confirm the accounts given of them by SACHS. Where the first pair of leaves is given off in *S. Martensii*, a slender spiral or scalariform duct passes from each leaf into this procambial layer, through which the two vessels descend vertically into the stem at points corresponding, as SACHS correctly indicates, with the two foci of the ellipse, where it joins some vessels already formed in the stem itself. The second pair of leaves contributes a second set of vessels, which in like manner enter the procambial cylinder. We thus obtain, partly from the stem itself and partly by successive additions from the various leaves, two parallel columns of fibro-vascular tubes separated by the central mass of procambium. Descending still lower into the matured parts of the stem, we find that,

* *Selaginella denticulata* appears to have the same structure as *S. Martensii*. See SACHS's 'Lehrbuch,' fig. 89 A.

by successive centripetal growths, these vessels have so increased in number as to cause the two bundles to meet in the middle of the procambial cylinder, through the longer axis of the transverse section of which they now form a continuous line. The central vessels of this linear series are now the largest. A further distinction appears in the circumstance that the central vessels are generally more perfectly scalariform, whilst the outer vessels are spiral ones. Whilst these changes have been going on, corresponding ones have connected the remaining procambial cells into an interrupted ring of prosenchyma with somewhat thickened walls, or, in other words, into a ring of limiting tissue, making the whole axis a closed bundle. The cortical layers appear to be composed of meristem; that is, they do not grow from any true cambial structure, but by the division of the preexisting cells of all the parts, until the normal dimensions of each stem are reached. The central vascular bundle of the axis thus represents the Xylem, and its investing prosenchyma the Phlöem, whilst the bark derives its existence from an independent source, originating in the primitive cellular tissue. In the plant quoted most of the vessels of the fibro-vascular bundles appear to be derived from the leaves. The outer vessels of these bundles are smaller in size as well as more spiral in structure than the inner ones. These facts have an important bearing upon the interpretation of our fossil forms. NÄGELI has argued that the fibro-vascular bundles belong to the stem and not to the leaves, because he finds such bundles in *Psilotum*, in which the leaves are deprived of them; but the *Psilotum* is altogether so exceptional a form that it can scarcely outweigh the evidence afforded by the *Lycopodia* and *Selaginellæ*.

Guided by these examples, I think we can ascertain the homologies of the fossil stems so far as their tissues are represented in the living types. It is clear that the central bundle of Plate XLI. fig. 2 corresponds substantially with a young state of the central fibro-vascular bundle of *Selaginella Martensii*, only here some of the central primitive tissue has remained to form the basis of a future pith which has no existence in the living forms. In the latter we have no central axis preserved which can, by the utmost stretch of the imagination, be identified with a pith; their primary central axis of procambium is wholly converted into or replaced by the central vessels (Xylem) and the investing zones of prosenchyma (Phlöem). Parenchyma has no longer an existence in this part of the plant; hence we must conclude that the preservation of a central portion of primitive parenchyma, capable of very considerable increase by cell-division, is peculiar to the fossil types.

We have seen that the number of the vessels in the central vascular bundles of living types increases, up to a certain point, with age, and also that each foliar vascular bundle unites with those of the central axis, at least where the first two come in contact and for some distance down the stem, at the external surface of the central bundle. The fossil and recent forms agree in this point; but we now face a difficulty. The number of the vessels in such a cylinder as I have represented in Plate XLI. fig. 8 represents, doubtless, the aggregation of the bundles of a yet larger number of leaves than there are vessels; and if each leaf of the upper part of the stem added its quota to the whole externally

to all previously formed ones, it is difficult to understand why we do not find the lower ones traversing tangential sections of the medullary cylinder, as we do in corresponding sections of the exogenous zone (Plate XLII. fig. 12). I think there can be no doubt that the large inner vessels of the vascular medullary cylinder belong directly or indirectly to leaves located at points of the stem inferior to those smaller ones belonging to the periphery of the circle. Yet in radial sections we witness the anomalous arrangement represented in Plate XLII. fig. 12, where the leaf-bundle (*m*) joins the cylinder (*c*) at a point external to the larger vessels of *c*, but which latter is connected with leaves higher up the stem than that supplied by the vessels *m*. At *m'* we still find the foliar bundle retaining its position external to the cylinder. I can only conclude that as they descend into the stem the vessels of each foliar bundle pass inwards, but do so obliquely and slowly, thus preventing their altered direction from being conspicuous in tangential sections of the cylinder. This peculiar difference in the arrangement of the upper and lower extremities of the foliar vessels may explain the sinuous course which those of the medullary cylinder pursue. They never exhibit the mutual parallelism seen in those of the ligneous zone, but twist about, so that they rarely preserve such parallelism, for any distance, either with each other or with the plane of the section*.

But supposing this peculiarity in their arrangement to be explained by what I have stated above, there yet remains another problem to be solved. We have seen that, in the first instance, these medullary vessels are few in number, and exhibit scarcely any central medullary area, whilst at later periods of growth opposite conditions prevail in both these respects. The pith becomes larger as the branch increases in size, involving a corresponding enlargement of the vascular ring composing its peripheral boundary. This could only be accomplished either through the pressure of the growing pith causing *displacement* and *rearrangement* of the surrounding vessels, or by producing *absorption* of the inner ones, the loss of which must, in that case, have been antagonized by a constant addition of new ones at the periphery. But after what I have seen of the displacement *of older vessels through the pressure occasioned by the growth of newer ones*, I have no hesitation in adopting the former of these explanations; the more so, since I have not in any instance seen such ragged irregularity in the vessels in contact with the medulla as continuous absorption would produce. Plate XLII. fig. 15 demonstrates that the real condition of things is precisely the reverse of this, the cells of the pith and the vessels of the cylinder adapting themselves to one another with geometric regularity. After the development of the foliar bundles and their aggregate product the vascular medullary cylinder went on for some time, an altogether new set of vessels began to be formed laying the foundations of my exogenous growths. These differ from those of the cylinder in almost every respect, whether of origin, structure, or function. 1st, as to origin: they are not, directly or indirectly, associated with the leaves; hence the foliar bundles have had nothing to do with their production. They have been formed in unequal concentric rings, in immediate contact with the inner layer of the bark. It

* These peculiar arrangements are represented in the diagram, Plate XLV. fig. 36.

must not be forgotten that the homologue of the vascular bundles of the living Lycopods, *i. e.* the vascular medullary cylinder, is not encased within a ring of prosenchymatous cells, or Phlöem, as in the recent plants: hence they remain throughout their entire development open and not closed bundles, which is a very important distinction. So far as I can judge, the appearance of this exogenous growth possibly corresponded with the period at which the leaves ceased directly or indirectly to produce further increase in the number of the vessels of the medullary cylinder. I can discover no reason for supposing that the number of the vessels of that cylinder subsequently received further additions, or that any further enlargement took place in the diameter of the cylinder. I can only account for the development of the exogenous layers by supposing the existence of some equivalent of a cambium-layer surrounding and parallel to the cylinder. The fact of these growths taking place as I have already described is beyond all question. The only debatable points refer to the source whence these exogenous layers were derived, and to the relations which they bear to the similar structures of other plants.

Professor M'NAB, who objects to my views on this point, lays much stress upon the distinction between a layer of "*meristem*" tissue and a cambium-layer. The distinction between these structures was made by NÄGELI and further illustrated by SACHS (Lehrbuch der Botanik, p. 75). The characteristic feature of a *meristem* structure is that all or most of its cells are capable of spontaneous division or multiplication by fission, as is the case with the first-formed elements of every plant; whilst such cells as are no longer capable of undergoing such divisions become *permanent* tissues. SACHS points out that these meristem tissues were formerly comprehended in what was generally termed cambium; but he urges the advisability of limiting this latter expression "to that meristemic (*merismatische*) layer in the tissues of the older parts of the plant by which is effected the lateral growth (*Dickenwachsthum*) of the Dicotyledons and Coniferæ." Hence, as cell-fission occurs in the true cambium-layer as well as in meristem layers, one chief peculiarity of the former lies in its position relative to the older parts of the stem—or, in other words, to its location, in the case of Dicotyledonous plants, between the wood and the bark. HENFREY describes some of the peculiarities of the Dicotyledonous stem as follows:—"When the buds open to produce new shoots, cell-division recommences in the cambium-region of the old bundles, and an additional layer of wood is added gradually during the season to that formed the year before. Season after season this process is repeated" (Elementary Course of Botany, p. 521, 2nd edition). "The medullary rays which separate the primary bundles are developed in the cambium-region with the yearly layers of wood, and always extend to the cortical parenchyma" (*loc. cit.* p. 523). HENFREY also points out, as other writers have also done, that one chief peculiarity in an exogenous stem resides in the parallelism of the cambium-layer to the previously formed fibro-vascular bundles (*loc. cit.* p. 518), and in the periodic resumption of activity in the bundles (*id.* p. 519). If all these conditions are not fulfilled in the specimens which I have described and especially illustrated by Plate XLIII. fig. 20, I know not where to seek for such a fulfilment in any living plant. But SACHS

further says, "das echte Cambium der Dicotyledon dagegen erzeugt sowohl nach aussen als nach innen fibro-vasale Gebilde, nach aussen Phlöem, nach innen Xylem" (*loc. cit.* p. 397). If this determination that a cambium-layer must develop tissues on both its inner and outer surfaces is to be accepted, there is no further room for discussing the matter. We shall see directly that I find no reasons for believing that the bark increased its inner surface by *prosenchymatous* additions from a true cambium-layer, and we have nothing in the interiors of these stems corresponding with the ordinary wood-cells of the Dicotyledons and Coniferæ. I have never for a moment pretended that we find in these arborescent Cryptogams all the features of a highly developed exogenous Dicotyledon. Primarily seeking to show the absurdity of applying the term *acrogens* to these plants, I have done so by demonstrating that they grow by the addition of new layers to the periphery of the old ones, that their woody wedges are disposed in radiating laminæ, as in the Coniferæ, and that these laminæ are separated by medullary rays of which the cells exhibit a mural arrangement. Whatever name may be given to the genetic material out of which these new investing layers develop, whether we choose to term it cambium or meristem, we have here very manifestly a form of exogenous growth.

That this exogenous structure belongs, as Professor KING long ago pointed out, to a system of vessels wholly independent of and distinct from the medullary cylinder is clear. What its functions may be is not equally clear. It undoubtedly gave strength to the trunk and branches of the tree, but it contributed nothing *directly* to the nutrition of the leaves. The leaf-bundles pass through it, but they clearly have no further connexion with it than results from that positional relationship. When I wrote the second memoir of this series I had not ascertained so clearly as I have since done the relations of these foliar bundles. Two facts, however, require further notice. One is that in that memoir I described a unique bit of a *Diploxylon*-stem in which some vascular bundles *were* given off from the ligneous zone, but whether or not they were foliar I cannot say*. The other relates to *Stigmaria.* That this is the root of a Lepidodendroid plant is unquestionable. It is also well known that the vascular medullary cylinder is not represented in it. The pith, which is large, is in direct contact with the inner surface of the exogenous woody zone. Remembering the apparent origin of the medullary cylinder from the leaf-bundles, we can understand the possibility that the downward prolongations of them would not reach the roots. But, as I have illustrated in my last memoir, the exogenous woody axis of *Stigmaria does* give off the vascular bundles to the rootlets. Hence it would appear that the nutritive fluids were absorbed by the rootlets and transmitted up the stem primarily by the vessels of the exogenous zone; but in order that those fluids should reach the leaves, they had to be transferred, by some lateral movement, to the vessels of the medullary cylinder. I do not propound this otherwise than as an hypothesis; but I can see no other way in which the end could be attained.

* I think it more than probable that this curious specimen may belong to that part of the base of the stem where the medullary vascular cylinder of the latter and the woody zones of the roots with their peculiar Stigmarian structure somewhat overlap one another.

There yet remains to be considered the relations which subsist between the respective cortical layers of the extinct and living Lycopodiaceæ.

In the former we have substantially three layers—an inner one of parenchyma composed of cells having a tendency to become arranged in vertical lines, an intermediate layer of prosenchyma, in which, in old stems, a peculiar, vertically elongated tissue tends to develop itself, and an outer parenchyma of the ordinary type, and which also constitutes the principal tissue of the leaves. If we combine what we find in the cortical investments of the recent Lycopods *Selaginella Martensii* and *Lycopodium chamæcyparissus*, we shall be furnished with all that we require to illustrate the identity between these tissues in the living and the extinct forms. In *Selaginella Martensii* we have an inner layer of parenchyma enclosed in an outer one of prosenchyma, which latter becomes more compact, in consequence of the increasing thickness of the ligneous deposit within its cell-walls, as we proceed from within outwards. No true epiderm invests the stem. In *Lycopodium chamæcyparissus*, on the other hand, we have no inner parenchyma, but the prosenchymatous layer, very much thickened*, closely invests the central vascular axis. External to this prosenchyma we have a distinct parenchymatous layer, which SACHS describes as being an extension of that composing the leaves. Thus these two living plants combine to furnish us with the three layers of bark found in the fossil ones. It is interesting to remember that in one of the fossil Lepidodendroid stems from Lancashire and Yorkshire described in my last memoir, I found the very thick prosenchymatous layer apparently in close contact with the vascular tissues, as in *Lycopodium chamæcyparissus*. It will be noted that no true epiderm invests the stems of either of these recent species, but it exists in the leaves in a well-defined form and with the usual stomata. In that position it rests immediately upon the foliar parenchyma, which, as we have seen, extends over the entire stem of *L. chamæcyparissus*, as it does over the fossil stems. Hence in the latter I have designated this superficial parenchyma the *subepidermal* layer, though I have seen no trace of true epidermis investing it; but this term assists us in maintaining correct relationships between the nomenclature of the recent and fossil types.

I have hitherto said nothing about the probable roots of the plant described in this memoir; but since the Burntisland beds are permeated in every direction by Stigmarian rootlets, specimens of the thick roots also being far from rare, I have come to the conclusion that they belonged to the same plant as the Lepidodendroid stems and branches. I am the more inclined to adopt this conclusion from the circumstance that I have not yet seen in this deposit a single fragment of a true *Sigillaria* to which these numerous roots could have belonged. Mr. BINNEY has more than once affirmed the probability that *Lepidodendron* had a Stigmarian root, which opinion I fully endorse.

Having satisfied myself of the soundness of these conclusions, I venture to suggest that Plate XLV. fig. 37 may be regarded as a diagrammatic representation of a vertical section of a typical Lepidodendroid tree, drawn in accordance with the various details described

* SACHS, 'Lehrbuch,' fig. 89 B.

in the preceding pages. At its upper portion we have on the left hand the leading shoot, and on the right the lateral branch of a *Lepidodendron*, with their leaves *in situ* and the central vascular axis of each limited to a medullary cylinder (*c*) enclosing a true pith (*a*). Lower down we have the later-formed layers of the exogenous zone (*d*). The leaves are here represented by their petiolar bases (*l'*), whilst yet lower we find that these have disappeared, leaving only the ordinary Lepidodendroid scars (*y*). Below the level of the black ground-line we have the Stigmarian roots, with their rootlets (*o*) and their rootlet-bundles of vessels (*n*), derived from the exogenous zone (*d'*).

In my last memoir I described a very peculiar variety of bark which I frequently found associated with the Lancashire forms of *Diploxylon*. Nothing resembling it occurs in the bark of the Burntisland type. In one of the Lancashire types, as I have already stated, I found the cells of the medullary rays thickened by internal bands of lignine, rendering them scalariform. No such cells appear in the Scottish plant. These are probably specific distinctions, to learn the exact value of which will require prolonged research.

I have now brought together the representatives of four distinct genera. The young twigs which I have described, whether we are guided by their outward forms or their internal structure, are true *Lepidodendra*. The older and larger branches and stems have the internal organization of a *Diploxylon* with the external bark and persistent petioles of a *Lomatophloios*, whilst the branching stems, with their double ligneous axes, are unmistakably identical with the *Leptoxylon* of CORDA*. The broad features of resemblance in the cortical and petiolar portions of my plant to CORDA's minutely described *Lomatophloios crassicaule* are too manifest to require that I should dwell upon them. The disciform Sternbergian pith of CORDA's species does not recur in any of our British forms. All such modifications of pith that have come under my notice continue to be correctly located where I placed them many years ago, viz. in the woody cylinders of Dadoxylons. But the possession of a disciform pith is not recognized as constituting a generic distinction amongst recent plants, and we need not give it that value amongst fossil ones. CORDA's genus *Leptoxylon* was founded upon a single decorticated axis, which, so far as it remains, displays no single feature differing from those of *Diploxylon*, except in the double character of the axis. BRONGNIART has already shown that this feature was but a result of the branching of the stem, and I have further illustrated the same truth in the preceding pages. Of the above names, the most appropriate one to be retained would be that of *Lomatophloios*, were it not clear that this is also a synonym of STERNBERG's older term *Lepidophloios*†: BRONGNIART has already adopted the latter name, uniting with it CORDA's genera *Lomatophloios*, *Leptoxylon*, and *Calamoxylon*, STERNBERG's *Cycadites columnaris*, and GOEPPERT's *Pachyphyllum*‡, all of which generic terms except *Cycadites* he abandons. It is obvious that *Anabathra* and *Diploxylon* must

* Flora der Vorwelt, tab. 15, p. 21.

† Dr. DAWSON further considers *Ulodendron* to be merely a synonym of *Lepidophloios*.

‡ Tableau des genres de Végétaux Fossiles, pp. 43, 44.

share the same fate, there being no longer any independent grounds for their retention. I propose therefore to adopt the generic term *Lepidophloios* for the plant which is the chief subject of this memoir. The necessity for the destruction of several genera just indicated suggests the probability that a number of specific names will have to suffer in like manner. I am satisfied that all attempts to apply specific names to the plants of the Coal-measures can but be provisional, until we learn more than we at present know of the effects of age upon their form and organization. Still, though they may not have any permanent value, such names are necessary for working purposes. I would therefore provisionally distinguish the subject of this memoir as *Lepidophloios brevifolium**.

I cannot close this memoir without expressing my obligations to Dr. DAWSON, of Montreal, who first directed my attention to the Burntisland deposit, and yet more to G. GRIEVE, Esq., of Burntisland, by whom the deposit was discovered. I am not only indebted to the latter gentleman for his personal guidance to the locality whence the fossil plants are derived, but he has laboured most indefatigably to keep me supplied with abundance of raw materials upon which to pursue my investigations. The deposit itself is a very remarkable one, apparently consisting of detached masses of peat imbedded in volcanic amygdaloid. Here and there fragments of the fossil plants occur charred to the extreme of blackness, but such is not their ordinary condition; they are usually of a rich brown colour, and the perfect way in which their most delicate organization is preserved leaves little to be desired.

APPENDIX.

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Since the remarks on page 306, relative to the growth of the new vascular layers of the ligneous zone of the *Lepidodendra* were penned, I have endeavoured to satisfy myself yet more thoroughly respecting the relations which this subject bears to the views of modern botanists on the general question of new vascular growths. Some years ago physiologists would have agreed to regard the new vascular layers described in this memoir and its predecessor (Part II.) as the products of a cambium-layer. Latterly,

* In a letter from Dr. DAWSON, dated Nov. 28, 1872, that observer informs me that he regards the Burntisland plant as identical with *Lepidodendron Veltheimianum*. Mr. CARRUTHERS, on the other hand, rejects this identification. Until the very characteristic macrospores of my plant are shown to exist in some of the localities in which the *Lepidodendron Veltheimianum* is common, I think it best to retain my proposed provisional name. I find these macrospores associated with a section of WITHAM's original specimen of *Anabathra pulcherrima*, for which I am indebted to Professor KING, and have not a doubt that the latter is identical with the Burntisland plant; but I have not sufficient proof to establish this point with the certainty requisite for a scientific determination. I trust that the Geologists of the Scotch Survey will succeed in obtaining from WITHAM's locality of Lennel Braes the decisive evidence which I doubt not will some day be forthcoming. Professor GEIKIE kindly informs me that he regards the Burntisland deposits as belonging to the upper part of the calciferous sandstones of the Burdichouse series, and that the Lennel Braes rocks belong to nearly the same stratigraphical horizon.

however, the German botanists especially have restricted the application of this term to a more special set of phenomena than was previously done. They now limit the expression cambium to a cellular layer which originates in a peculiar way, and which develops new tissues in a manner equally special, both processes being illustrated by what occurs in the majority of Dicotyledonous and Gymnospermous Exogens. In these plants the young aërial buds and the tips of the young leaves and roots severally contain the special homogeneous parenchyma to which SACHS has given the name of "procambium." The foliar fibro-vascular tissues are developed, in the first instance, in this procambium; and on tracing each bundle so formed down into the stem we find, in Dicotyledons and Gymnosperms, that its fibro-vascular elements are produced on both the central and the peripheral sides of the procambial mass. For those tissues which are produced on its inner or medullary surface, corresponding with the new wood of English botanists, some Germans assign the name of Xylem; whilst to the tissues formed on the outer or peripheral side they give the name of Phlöem, which is the equivalent of our English liber or endophlœum. These two elements of permanent tissue are developed centripetally, so far as each isolated string of procambium is concerned, until they almost meet in the centre, having used up in their growth a considerable portion, if not all, of the procambial cells. At this stage the detached fibro-vascular bundles are separated from each other by some of the primitive cells constituting the primary medullary rays. The growth of the second year commences by the extension of the cambium-tissue, as interfascicular cambium, across the outer ends of these primary rays by the usual process of cell-fission, to which the German botanists give the general name of Meristem. Instead of the cambium continuing as a circle of isolated vertical strings, it now forms a continuous cylinder, which repeats, on an enlarged scale, the operations of the previous year, with the addition of lengthening the preexisting medullary rays by adding new mural cells to the outer extremities of those in the Xylem layer, as well as to the inner ends of others separating the Phlöem bundles. The Germans designate the latter the Phlöem rays, in contradistinction to the Xylem rays separating the growing wedges of true wood.

As I have already shown, nothing that exactly corresponds with the details of these processes has taken place amongst the fossil Cryptogams which I have described; hence I cannot affirm that the latter possessed a cambium ring in the sense to which I have just referred. But that a process of new cell-growth has led to the development of a succession of enlarging woody zones, each in its turn enclosing more or less completely the preexisting ones, is certain.

But there are many obscurities which make it difficult to ascertain what are the exact analogies subsisting between the growth-processes in the recent Dicotyledons and fossil Cryptogamic plants. In the former, the primary ring of vascular bundles in the stem consists of an aggregation of individual leaf-bundles. The equivalents of this foliar series, as I have shown in the preceding pages, are to be found in my medullary vascular cylinder, which in the fossil Lycopodiaceæ is mainly, if not wholly, composed of prolongations of the true foliar bundles. So far as origin and position are concerned, this

medullary cylinder appears to correspond with the pith-crown (Markkrone) or pith-sheath (Markscheide) of the Germans; only it lacks, in the fossil forms, all the multiplied wood-cells of various kinds which enter into the composition of the Xylem portion of that structure, whilst the Phlöem layer has no true representative either at this or any subsequent stage of growth.

With the exogenous peripheral extension of the wood some new differences present themselves. In the case of the Dicotyledons and Gymnosperms, the fibro-vascular bundles of the medullary sheath, or "pith-crown," consist of elongated, annular, spiral, and reticular vessels, mingled with long wood-fibres; whilst in the new layers of secondary wood no spiral or annular vessels appear, their places being taken by what SACHS terms "short-membered, wider, pitted or dotted vessels"*. In the fossil Lycopods, as we have seen, the first exogenous zone is developed immediately around the vascular medullary cylinder, just as the first layer of secondary wood is developed immediately around the medullary sheath in the Dicotyledons and Gymnosperms. But instead of a change occurring in the nature of the vessels in such new layers of these Lycopods, corresponding with that just referred to in the living Exogens, the vessels of the new zone of the former are mostly identical in character, except in their smaller size, with those of the medullary vascular cylinder. If the former are barred, so are the latter; if the former are reticulated, so are the latter. But with this exception, the further development of these new zones proceeds so as to produce results substantially representing those seen in living Exogens. Thus a ring of detached vascular bundles first surrounds the vascular medullary sheath with definite vertical layers of mural cells between them, constituting the beginning of as many medullary rays. New bundles are added to the exteriors of the preexisting ones, as well as new cells to the peripheral margins of the medullary rays. As this intercalation of additional radiating vascular laminæ increases the tangential diameter of these bundles, new, and yet more peripheral, medullary rays become intercalated, as in living Exogens; so that, though these exogenous zones have attained, in many of the fossil Lycopods, to very large dimensions, no material increase takes place in the diameter of the individual woody wedges as they progress from within outwards. I have also shown in the preceding pages that these exogenous layers neither contribute to nor receive from the leaves any portion of their vascular elements; whilst, as shown in the case of the *Stigmaria*, they do furnish the vascular bundles going to the rootlets, and consequently act as the channels through which the crude sap has ascended from the roots to the upper portions of the tree. It appears to me that we have here an analogy of the utmost importance in relation to the problems under discussion. We seem to have here an identity of function which overrides all secondary differences of origin in its bearing upon the nature and homologies of these several structures, and which, when superadded to the structural resemblances existing between the exogenous ligneous zone of a Diploxyloid Lycopod and that of a recent Dicotyledonous tree, justifies my hypothesis as to the relations subsisting between the two in no slight degree, viz. that

* Lehrbuch, p. 540.

they foreshadow the cambial growths of a later age. But another question arises, viz. What is the genetic relation subsisting between the innermost cellular layer of the bark of a *Lepidodendron*, through the agency of which these new exogenous growths have been developed, and the cambium ring, which has accomplished a similar end in living Exogens?

I have already stated that the entire cortical layer of the fossil Lycopods corresponds much more closely with that of the recent ones than it does with that of any living Exogens. We find in it nothing identical with the endophlœum or liber of English botanists, the Phlöem of German ones. It is essentially a meristem tissue, the result of successive cell-fissions, and usually divisible into from three to four layers. We have, first, an outer parenchyma, which I have termed subepidermal, within which is a variously modified prosenchymatous layer. This is succeeded by an inner parenchyma, the innermost portion of which is usually more or less differentiated into a reproductive layer in which the successive exogenous zones are developed. I have got some magnificent specimens of bark which show that the two outer layers, viz. the subepidermal parenchyma and the prosenchymatous one, but especially the latter, increased in thickness through a meristem action which from time to time developed an abundance of new cells along the line of separation between the two tissues, and which process is illustrated by the curious specimens of bark described and figured in my second memoir (Phil. Trans. 1871, p. 220, Plate XXXI. figs. 54 & 57). The growth of these two outer layers being thus apparently accounted for, we have further to ascertain the corresponding process in the history of the inner parenchyma. That it also increases *enormously* in thickness with the increased age of the stem is quite certain; but though I have examined it in numerous specimens, I have wholly failed to detect any trustworthy traces of a *diffused* cell-fission or meristem process acting simultaneously throughout the entire substance of the layer. Such facts as I have observed seem to me to render it more probable that the new cell-divisions have taken place near its inner surface, and that, whilst these divisions were ultimately instrumental in adding to the thickness of the vascular ligneous zone on their inner side, they also increased the diameter of the parenchymatous bark-layer to which they belonged in the opposite direction. If this idea proves to be correct, it will follow that this meristem action of the innermost bark ends in the production of two kinds of permanent tissue—an inner vascular one, belonging to the vascular axis, and an outer cellular one, belonging to the true bark.

These meristem processes have evidently taken place interruptedly. There seem to have been periods of intense activity alternating with periods of rest. The latter state is illustrated by specimens of *Stigmaria* in my cabinet like that represented in Plate XXXI. fig. 52 of my second memoir*, where the outer parenchyma (*l*) passes suddenly and abruptly into the prosenchymatous layer (*k*), the peculiar meristem structures seen in figs. 54 (*h*) and 57 of the same Plate being entirely wanting. But these latter evidences of vigorous action are very conspicuous in other specimens which I have discovered since

* Philosophical Transactions, 1872, Part I.

the publication of that memoir, and the identity of which with those represented by fig. 52 is demonstrated by their possessing *in situ* the peculiar rootlets so characteristic of *Stigmaria*. I have not obtained similarly conspicuous proofs of this intermittent cell-action in the *innermost* bark; but the periodic additions made to the exterior of the exogenous vascular zone, as illustrated by fig. 21 of the present memoir, demonstrate that similar alternations of activity and rest must have occurred in this region. Hence we appear to have in these Cryptogamic Lepidodendroid stems two concentric vertical zones in which these alternations occurred,—one in the same region as is occupied in Dicotyledons and Gymnosperms by the true cambium-layer, and the other in the same plane as that which contributes to the growth of the cork-layer of the bark in the same plants*; and whilst fully recognizing the differences between the details of the physiological phenomena in the two classes of instances thus compared, I cannot believe that the coincidences referred to are wholly accidental. Be that, however, as it may, we are brought to the conclusion that though the *accessory* phenomena attending the exogenous growth of the stems of these fossil Cryptogams differ from those seen amongst the recent Dicotyledons, that process of growth practically leads to similar results in both cases, so far as the lateral expansion of the woody zone is concerned. The most striking difference between them lies in the entire absence of ligneous prosenchyma or wood-cells from the exogenous zone of the fossil types; but this is not more remarkable than the equally complete absence of the other, or vascular, element from the corresponding zones of a coniferous stem. In a letter which I recently received from Professor SACHS, referring to this subject, he says:—"The main point seems to me to be whether or not, in the case of Cryptogams, subsequent growth in thickness (Dickenwachsthum) occurs. Whether this takes place by means of cambium or merely by means of meristem, is manifestly a question of secondary importance." That such a growth does occur is now put beyond all possibility of doubt.

But the difficulties which surround these efforts to ascertain the homologies subsisting between the Carboniferous Lycopods and living plants are not confined to the exogenous zone. A somewhat similar difficulty attends the attempt to establish true homologies between the vascular medullary cylinder of the plants described in this and the preceding memoir and the central fibro-vascular bundles of the living Lycopods. That these two structures *are* homologous I have no doubt, nor, so far as I am aware, has any other observer. Professor SACHS agrees with this conclusion. He writes, "I consider that your medullary axis of fibro-vascular bundles consists of several such fibro-vascular bodies as I have depicted in fig. 310 in the second edition of my 'Textbook,'"—which figures represent sections of the stems of living Lycopods. But more than one difficulty presents itself when we try to work out the details of this relationship.

Our fossil *Lepidodendra* do not exhibit any thing which exactly corresponds with what I have described on pages 303 & 304 as occurring in the living Lycopods. I have already

* See M. RAWENHOFF "On the Formation of the Cork-bark in Dicotyledons," Annales des Sciences Naturelles, 5ième serie, vol. xii. p. 34.

shown that, as each branch grew, a rapid and very large increase took place in the number of the vessels constituting the medullary cylinder of the Lepidodendroid plants; but I have been unable to satisfy myself whether these new additions were developed centrifugally or centripetally as in living Lycopods. The difficulty of determining this point arises from a circumstance which marks an additional distinction between the living and the extinct forms. In the former, the vessels first produced in the procambial axis retain their relative positions permanently: the new vessels added to them merely occupy, in succession, the spaces intervening between older ones, without either disturbing the latter or enlarging the area which the entire bundle occupies. The case is wholly different with the Lepidodendroid plants: in them we have no evidence that the vascular elements developed in this manner. However we regard my medullary cylinder, whether as exclusively composed of foliar bundles or of a combination of foliar and stem-bundles as in living Lycopods, there is no perfect parallelism between its arrangements and those of the recent plants. Beginning in the fossil form at the tip of a twig as a small vascular bundle, we have seen that it gradually enlarged its area until it became a cylinder of considerable dimensions. Some of the primitive cells out of which the vessels were developed, and which I presume have been procambial, obviously increased by a prolonged meristem action until they produced a central axis of permanent parenchymatous tissue representing a medulla, the pressure occasioned by the growth of which was probably the cause of the centrifugal movements of the vessels composing the rudimentary vascular medullary axis. But whilst we may thus account for the displacement of the vessels, it is difficult to explain the origin of the numerous additions to their number in the vascular ring taking place coincidently with the growth of the stem. We find no traces of reproductive procambial cells interspersed between the vessels of this vascular zone. Were these additional vessels produced through the cells of the pith-meristem *within* the cylinder, or through those of the cortical one *external* to it? We must look to one of *these* sources for their origin; and my own impression is that their true source was the innermost layer of the cortical cells. If so, their development was centrifugal, or in the opposite direction to that of their living allies. But there is yet a further distinction to be recorded. We have seen that in the vascular bundles of the recent Lycopodiaceæ each central vascular bundle is flanked on either side by a layer of prosenchymatous fibre. I find no trace of any such tissue occupying a similar relation to the vessels of the fossil plants. In the latter these vessels are either unmixed with any cellular tissue whatever, as in the Diploxyloid forms of the cylinder, or they are distributed through a mass of mere parenchyma, which appears to be a permanent tissue, as in the medullary axis of *Lepidodendron selaginoides**. Thus we find that even in those structures which are generally accepted as the representatives of the vascular bundles of the living Lycopods, the fossil forms differ very widely from the recent types, both genetically and in their composition.

Such differences occurring in the central vascular axis (so universally accepted as

* Philosophical Transactions, 1872, Part 1, Plate XXIV. fig. 1.

presenting the same structure in the fossil and living Cryptogams) demonstrates that we must not expect to find in the primæval types exactly the same genetic phenomena as those with which we are familiar at the present day, when the differentiation of Cryptogams from Phanerogams has progressed so far by the degradation of the former and the elevation of the latter types. When no true Dicotyledons existed, their places being taken by an arborescent type of Cryptogams, the differences to which I have called attention prepare us for recognizing without surprise the possibility of other genetic distinctions, such as we find in the exogenous growth so generally characteristic of the Carboniferous plants.

Description of the Plates.

PLATE XLI.

Fig. 1. Transverse section of a young Lepidodendroid twig, enlarged 20 diameters.

Fig. 2. Transverse section of the tip of a yet younger twig, enlarged 24 diameters.

Fig. 3. Transverse section of the central vascular cylinder of fig. 2, enlarged 54 diameters.

Fig. 4. Transverse section of the central vascular cylinder of fig. 1, enlarged 54 diameters.

Fig. 5. Longitudinal section of a similar twig to fig. 1, enlarged 50 diameters.

Figs. 6, 7. Radial sections of the bark of specimens like fig. 1, enlarged 50 diameters.

Fig. 8. Transverse section of the vascular cylinder of a branch larger than fig. 1, enlarged 54 diameters.

PLATE XLII.

Fig. 9. Transverse section of a young branch which has reached the *Diploxylon* form, enlarged 2½ diameters.

Fig. 10. Radial section of a portion of the vascular medullary cylinder and ligneous zone of fig. 9, enlarged 55 diameters.

Fig. 11. Transverse section of the central axis of a large Diploxyloid stem, natural size.

Fig. 12. Tangential section of part of the ligneous zone of fig. 11, enlarged 10 diameters.

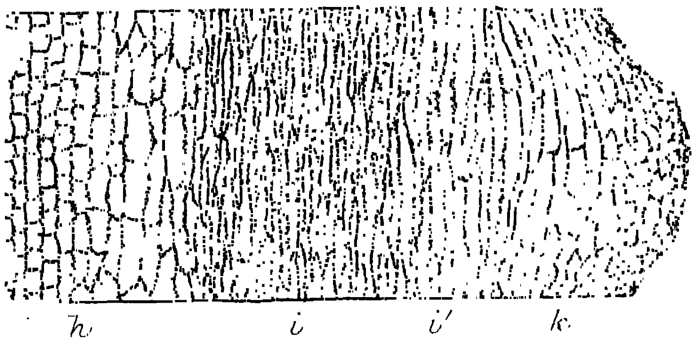
Fig. 13. Tangential section of part of the ligneous zone of fig. 11, yet further enlarged 32 diameters.

Fig. 14. Vertical section of the medulla and vascular medullary cylinder of a Diploxyloid stem, enlarged 12 diameters.

Fig. 15. Transverse section of a portion of fig. 14, exhibiting the junction of the vessels (*c*) of the cylinder with the cells (*b*) of the pith, enlarged 50 diameters.

Fig. 15*. Radial section of the outermost layers of the bark with leaf-petioles attached, natural size.

Fig. 6.



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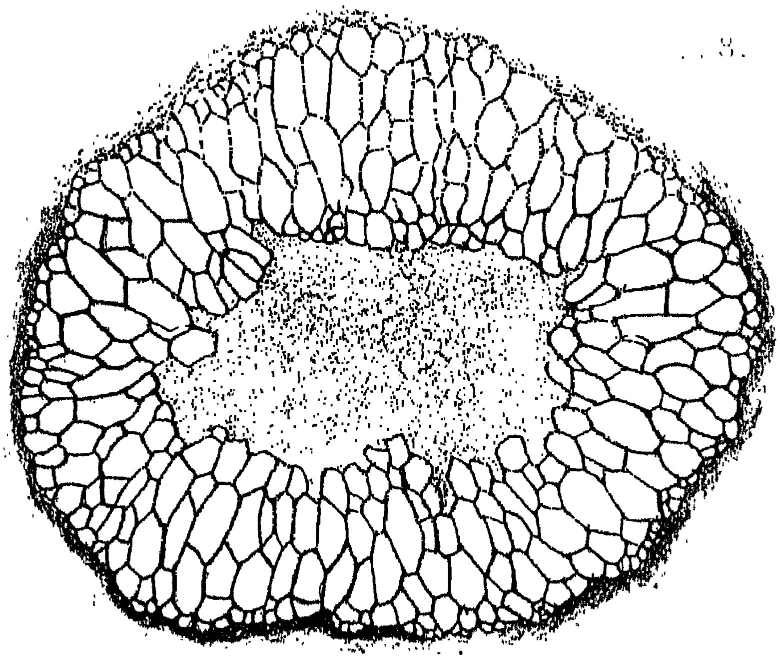
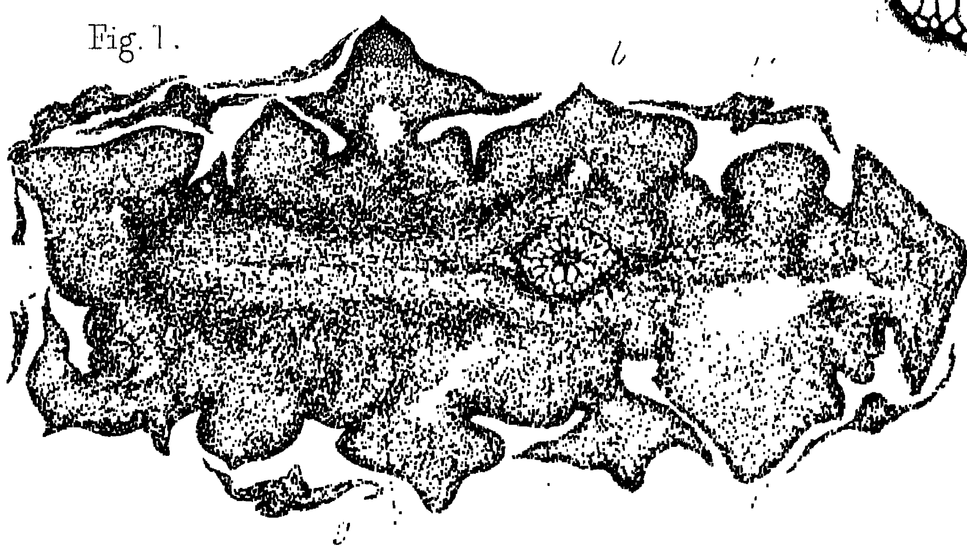


Fig. 1.



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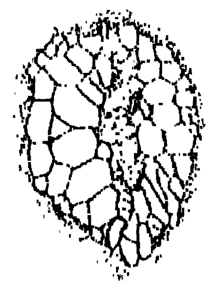

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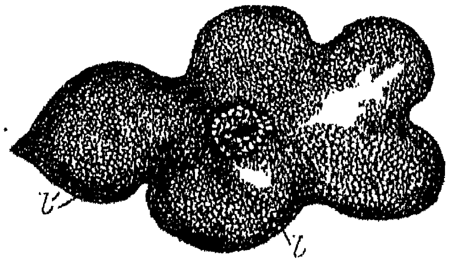

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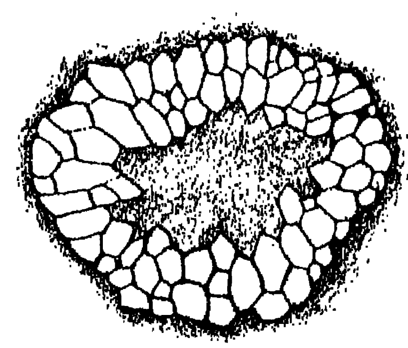

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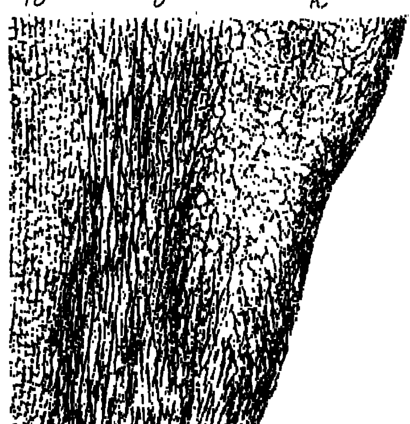

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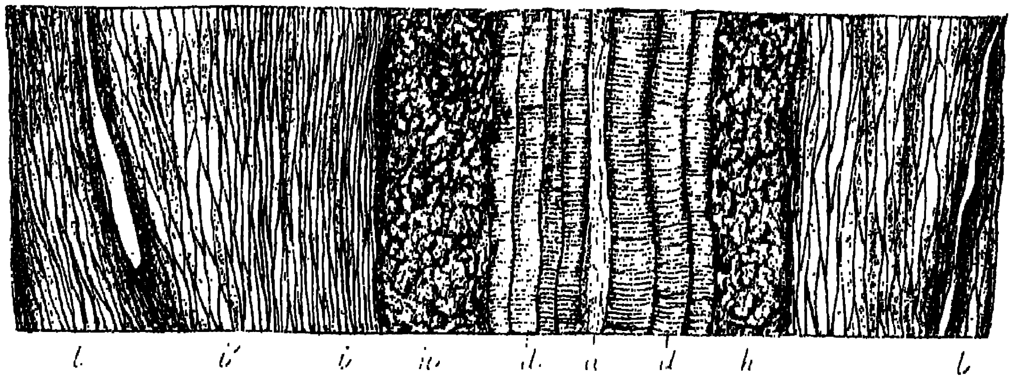

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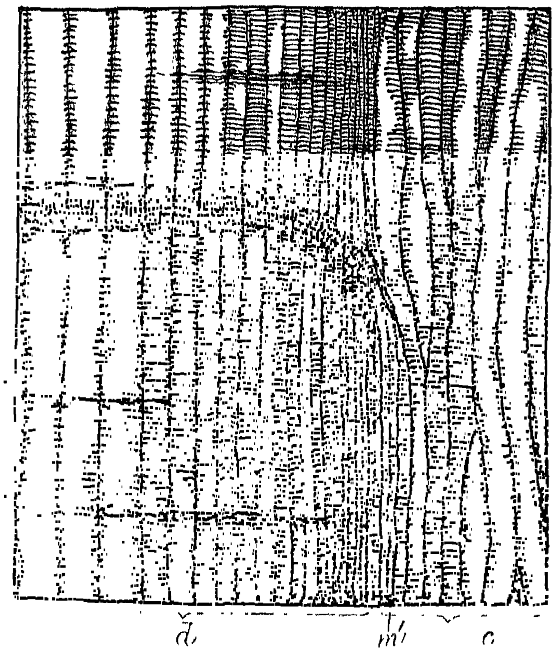
Fig. 10.



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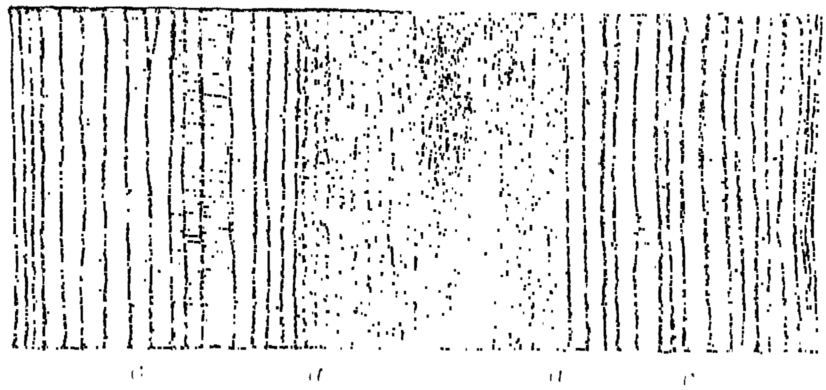

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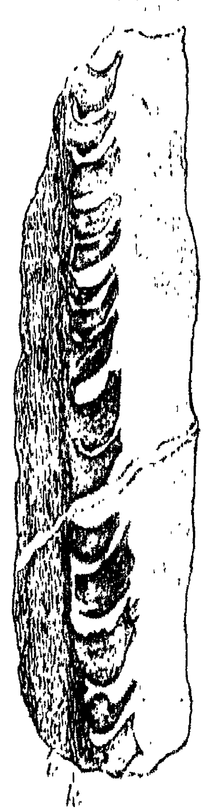

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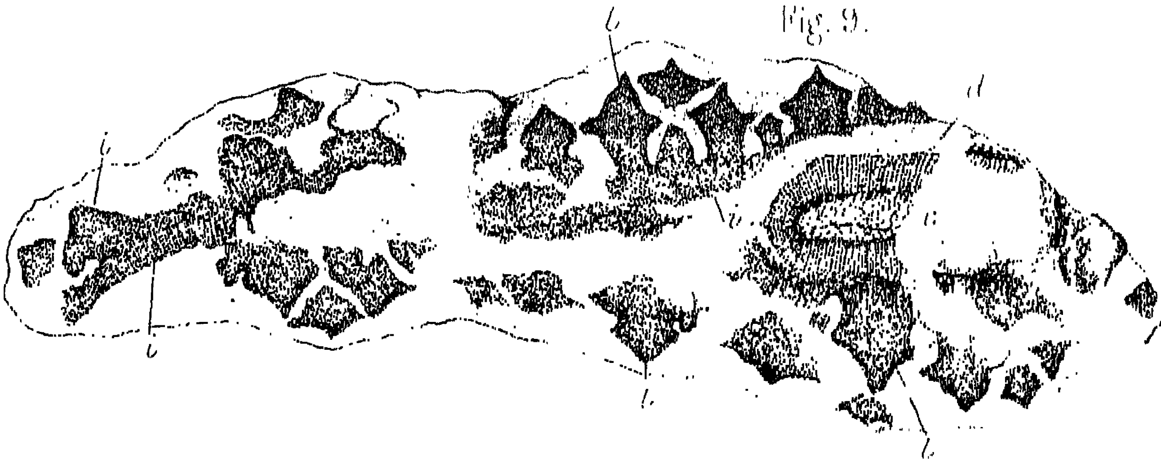

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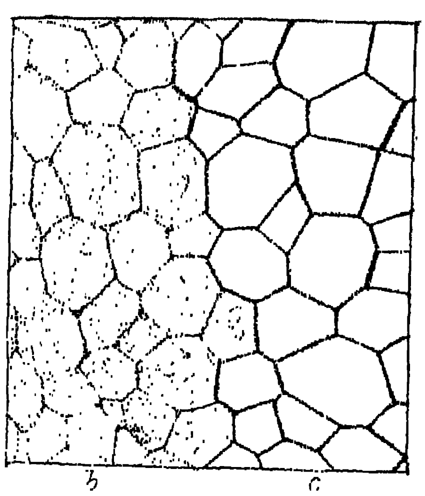

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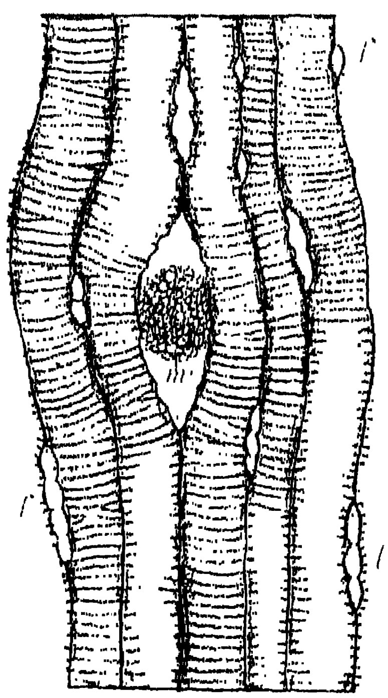

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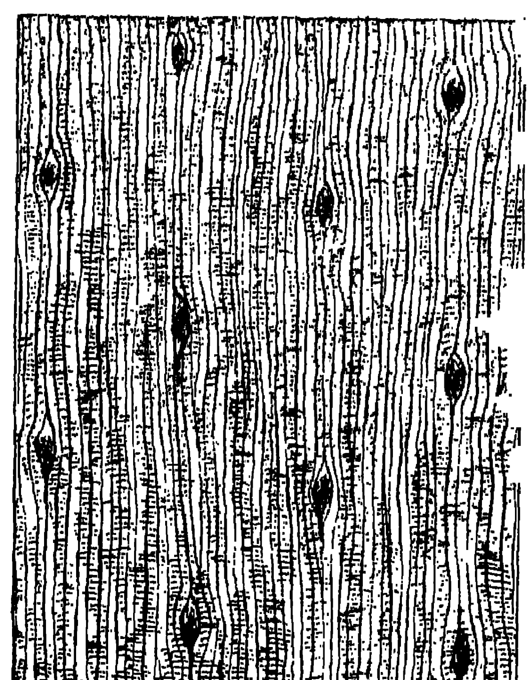

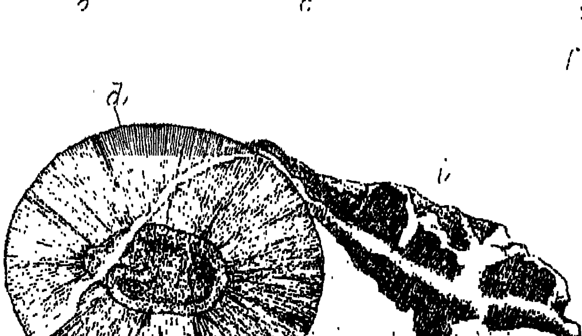

Fig. 11.

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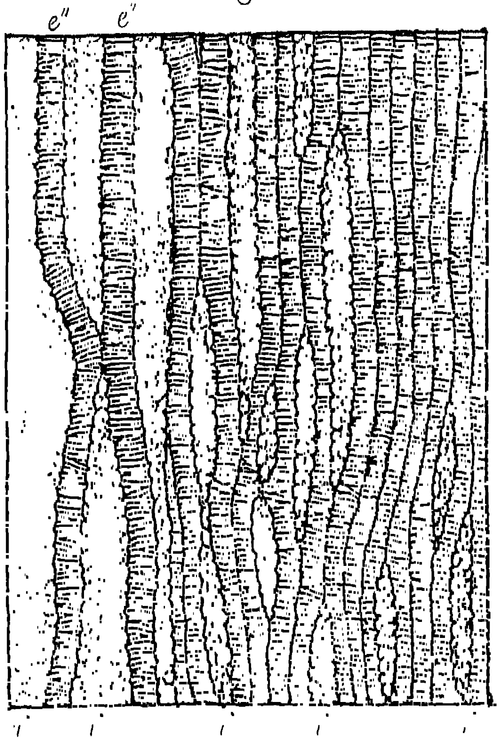
Fig. 22.



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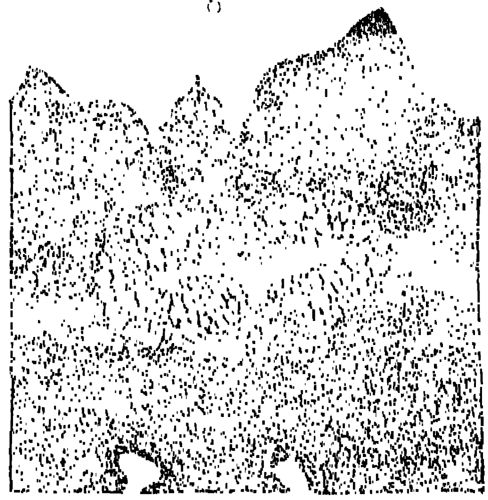

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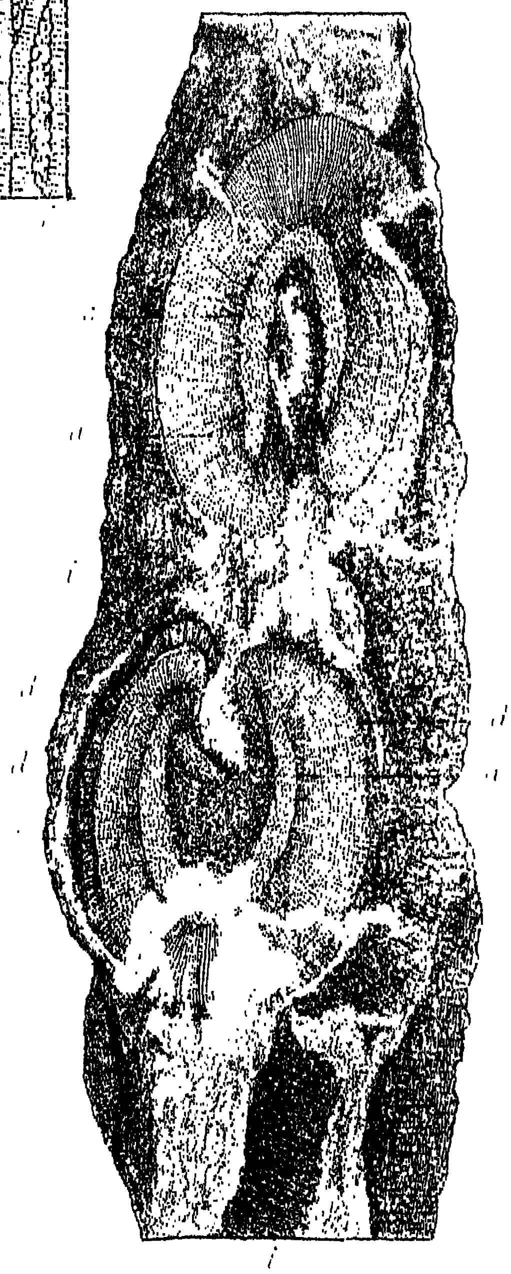

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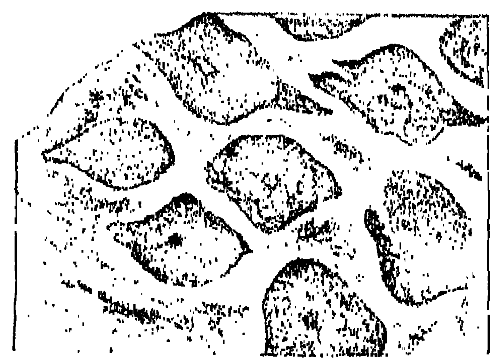

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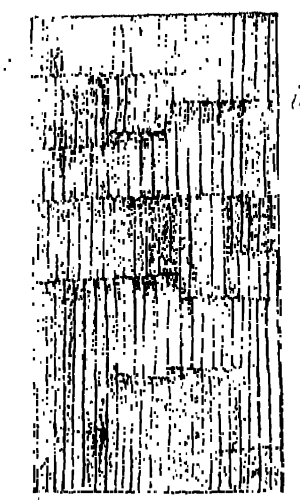

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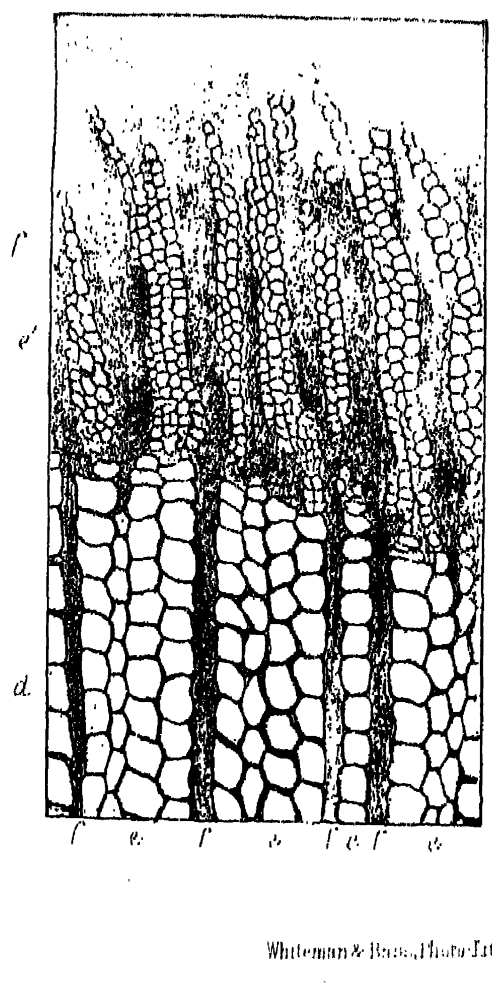

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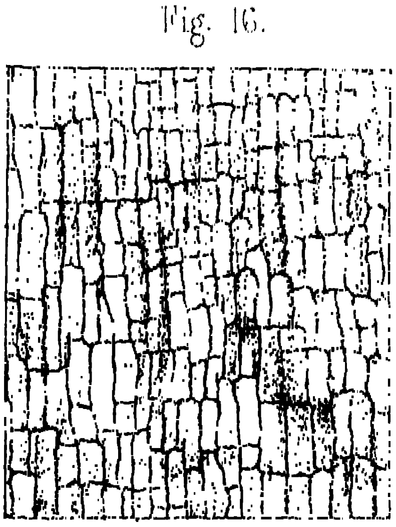

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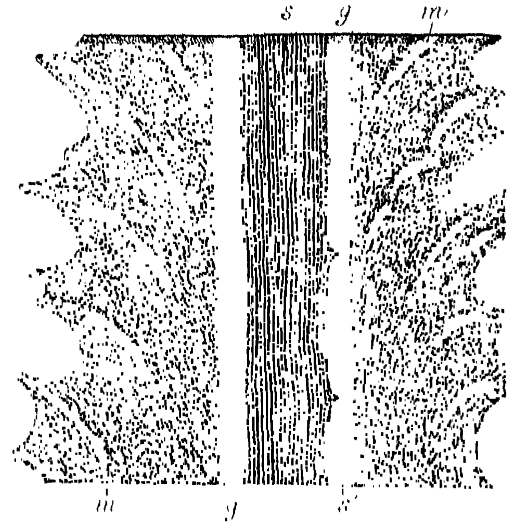
Whiteman & Bass, Photo-Lith.

Fig. 23.

Fig. 30.



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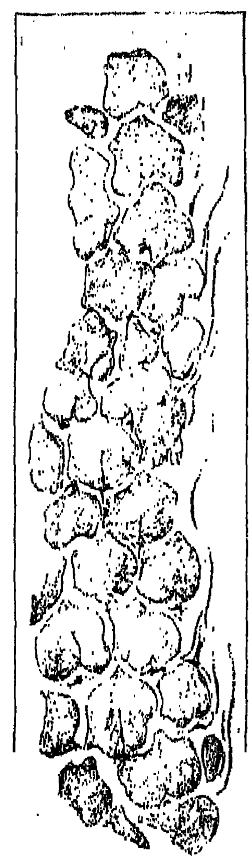

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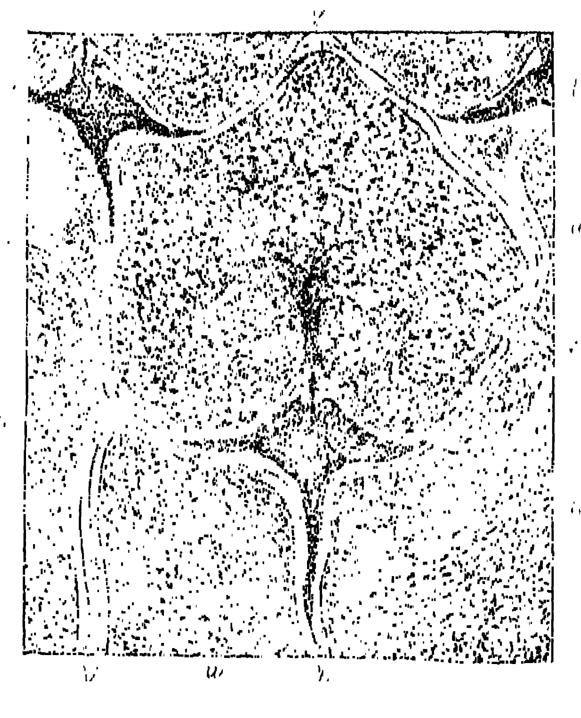
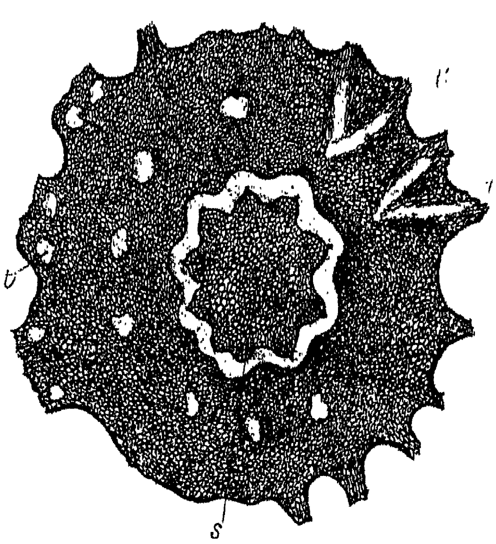


Fig. 27.

Fig. 29.



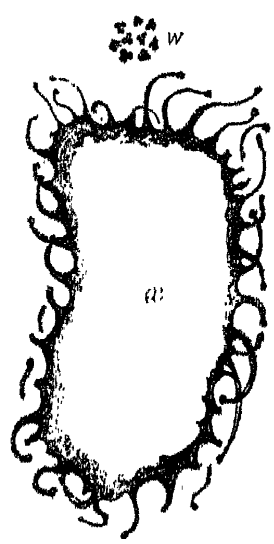


Fig. 27.

Fig. 28.

Fig. 35

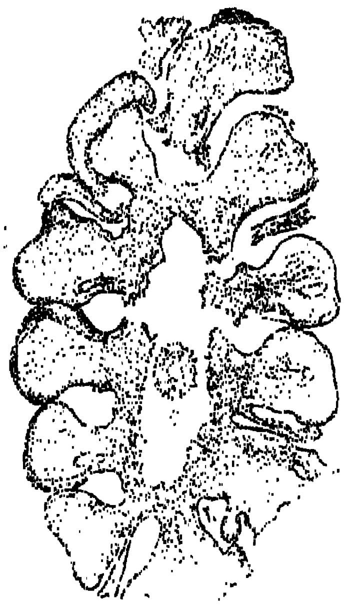
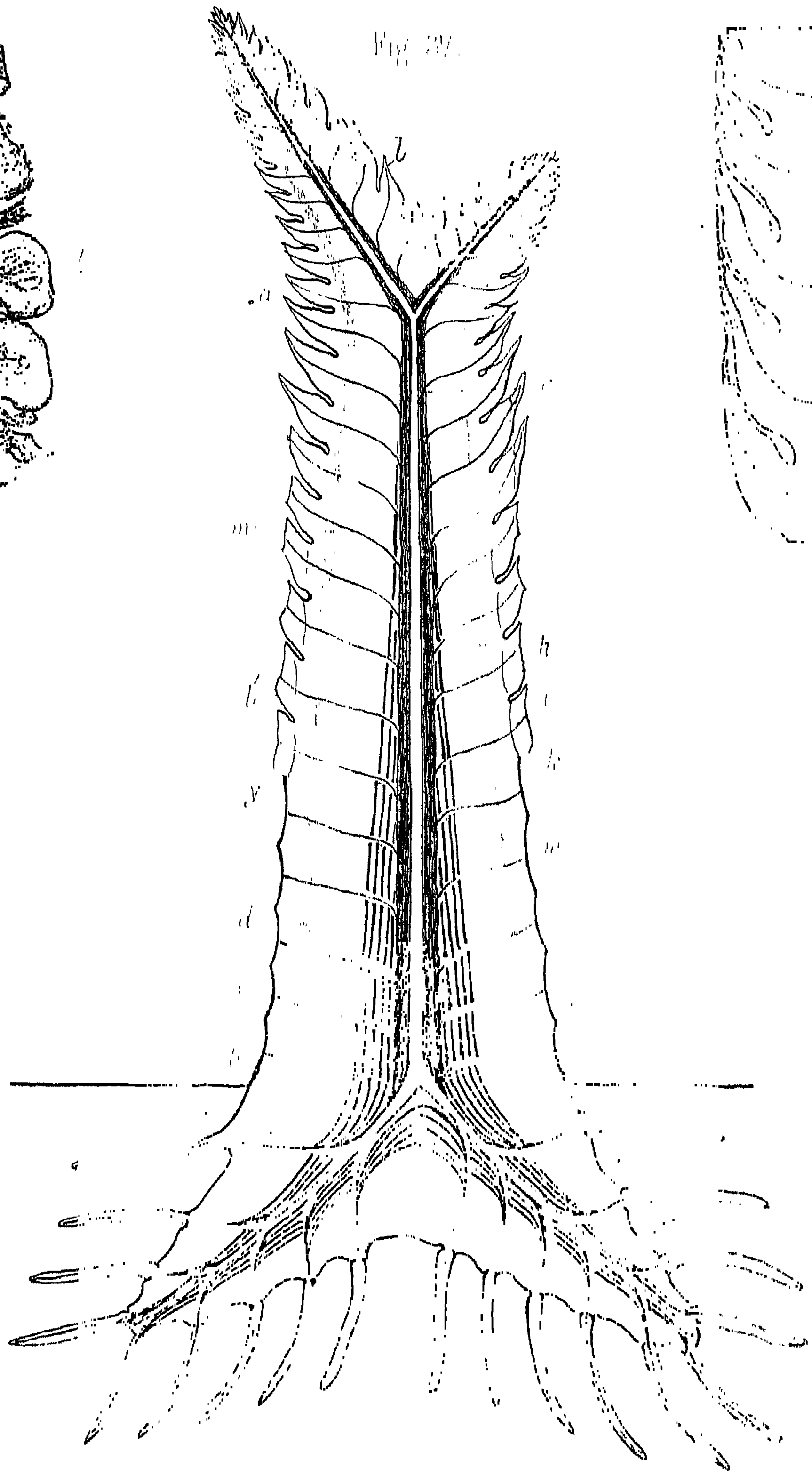


Fig. 37.



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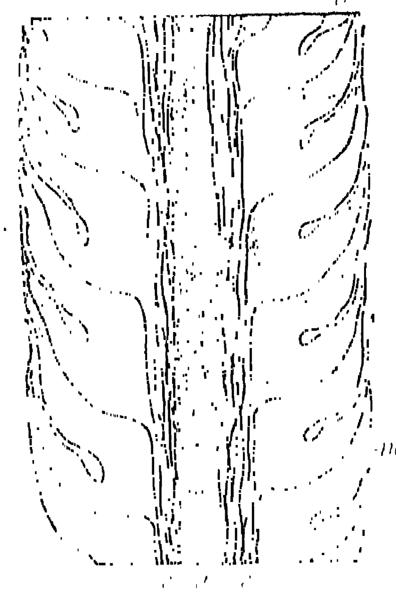
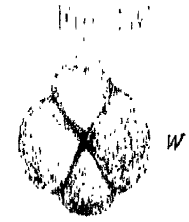


Fig. 31.

Fig. 38.



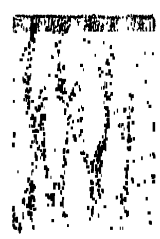


Fig. 32.

Fig. 34.

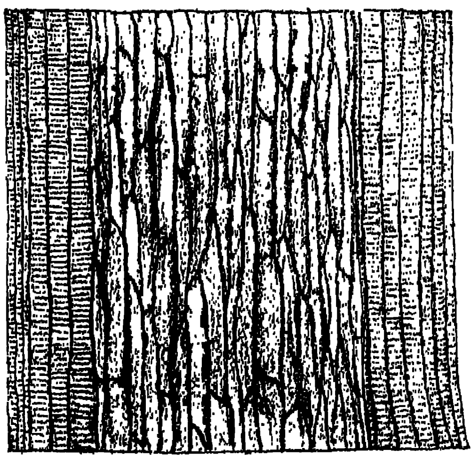
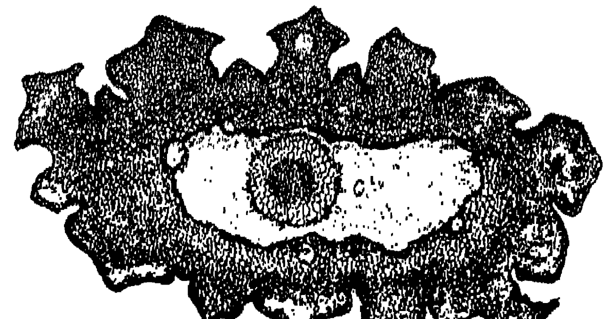


Fig. 33.



Williamson, Del.

Whiteman & Bass, Photo-Litho.

PLATE XLIII.

Fig. 16. Radial section of the inner parenchymatous bark in its matured state, enlarged 50 diameters.

Fig. 17. Radial section of the outer part of the prosenchymatous bark in its matured state, enlarged 40 diameters.

Fig. 18. Tangential section of the leaf-petioles close to the outer surface of the bark, enlarged 2 diameters.

Fig. 19. Transverse section of the centre of a young Lepidodendroid twig, about to branch dichotomously, enlarged 28 diameters.

Fig. 20. Section of a large Diploxyloid stem branching like fig. 19, enlarged 2 diameters.

Fig. 21. Transverse section of part of the ligneous zone of fig. 20, enlarged 40 diameters, exhibiting the young vascular growths.

Fig. 22. Tangential section of some of the young vessels of fig. 21, enlarged 50 diameters.

PLATE XLIV.

Fig. 23. Transverse section of a *Lepidostrobus*, enlarged 7 diameters.

Fig. 24. Tangential section of a *Lepidostrobus*, enlarged 4 diameters.

Fig. 25. Small portion of fig. 24, enlarged 45 diameters.

Fig. 27. *x*, Section of a macrospore, enlarged 70 diameters; *w*, cluster of microspores, enlarged to the same scale.

Fig. 27*. Single macrospore, external aspect, as an opaque object, enlarged 35 diameters.

Fig. 28. Cluster of four sporangia from the base of a *Lepidostrobus*, and containing macrospores, enlarged 32 diameters.

Fig. 29. Transverse section of the central axis or peduncle of a large *Lepidostrobus*, enlarged 10 diameters.

Fig. 30. Longitudinal section of fig. 29, enlarged 10 diameters.

PLATE XLV.

Fig. 26. Microspores of fig. 25, magnified 800 diameters.

Fig. 31. External surface of a young Lepidodendroid twig of the common type of fig. 1, enlarged 3 diameters.

Fig. 32. External surface of a young Lepidodendroid twig of a rarer variety, enlarged 3 diameters.

Fig. 33. Transverse section of a young Lepidodendroid twig from Oldham, enlarged 8 diameters.

Fig. 34. Longitudinal section of the medullary axis of a young Lepidodendroid twig from Oldham, enlarged 46 diameters.

Fig. 35. Transverse section of a young Lepidodendroid branch from Oldham, with large leaves, enlarged $4\frac{1}{2}$ diameters.

Fig. 36. Diagram representing the arrangement of the foliar bundles and vessels of the medullary sheath.

Fig. 37. Diagram representing a typical vertical section of a Lepidodendroid tree with Lepidodendroid branches, Diploxyloid stem, and Stigmarian roots.

The letters of reference employed in the above figures are applied as follows, the application being as nearly as possible identical with that of my previous memoir; I have given the list complete, though several of the letters refer to root-structures and other parts not described in detail in this memoir, and some additional ones are employed.

a. Medulla.
b. Medullary cells.
c. Medullary vascular cylinder.
d. Ligneous zone.
e. Vessels of ligneous zone.
f. Medullary rays.
g. Innermost parenchymatous bark (rarely if ever present in these Burntisland plants as a distinct layer).
h. Inner parenchymatous bark.
i. Prosenchymatous bark.
k. Subepidermal parenchymatous bark.
l. Leaf-petioles and leaves.
m. Foliar bundles of vessels.
n. Root-bundles of vessels.
o. Rootlet.
p. Cups for rootlets (not present).
r. Cone-scars (not present).
s. Axis of strobilus.
t. Bracts of strobilus.
u. Sporangium.
v. Cellular sporangium-wall.
w. Microspores.
x. Macrospores.
y. Leaf-scars.

XIV. *On the present amount of Westerly Magnetic Declination [Variation of the Compass] on the Coast of Great Britain, and its Annual changes. By Staff Captain* FREDERICK J. EVANS, *R.N., F.R.S., Hydrographical Department, Admiralty, in charge of Magnetic Department*.*

Received June 15,—Read June 20, 1872.

FROM the rapid decrease in late years of the amount of Westerly Magnetic Declination over the whole area of the United Kingdom and the adjacent seas, the attention of the Hydrographic Department of the Admiralty has been constantly directed to this interesting physical fact as one specially affecting coast navigation and the accuracy of compass-bearings derived from the current charts.

The duties of Her Majesty's Surveying-vessels engaged on our own shores having within the last few years included districts embracing nearly the whole extent of coast-line, the opportunities thus afforded for a careful determination of the magnetic declination at widely spread and favourable localities were, under the direction of Admiral RICHARDS, C.B., F.R.S., the Hydrographer of the Admiralty, taken advantage of, and suitable instruments furnished to the Commanding Officers from the Admiralty Compass Department.

Experience has shown that the accurate determination of the magnetic declination requires very careful manipulation and attention to instrumental details, and especially so if observed by the suspended collimator magnet, or by the reflecting apparatus devised by Dr. LLOYD and employed by the late Mr. WELSH in his Magnetic Survey of Scotland, in the years 1857–58, the account of which will be found in the Report of the British Association for the Advancement of Science for 1859.

Partly from these considerations and from the time required in the use of such delicate instruments, instead of them the well-known Admiralty Standard Compass was in general employed, supplemented occasionally with a KATER'S Azimuth Compass of superior construction. Every precaution was adopted to ensure the accuracy of the several adjustments of these instruments before they left the Admiralty Compass Observatory (now established in Her Majesty's Victualling Yard at Deptford) prior to the annual resumption of the duties of the surveying-vessels, as well as in the re-examination of their errors on return from the season operations.

The most extended of the series of observations recorded in this paper were made by Staff Captain E. K. CALVER in Her Majesty's Ship 'Porcupine,' assisted by Staff Commander GEORGE H. INSKIP; they include Stornoway in the Hebrides, Lerwick in the

* Communicated with the sanction of the Lords Commissioners of the Admiralty.

Shetland Islands, and the N. and N.E. coasts of Scotland, the eastern coast of England from Holy Island to the North Foreland, and the N.W. and N.E. coasts of Ireland. The final results are generally the mean of two and sometimes three compasses, the individual observations having been made on several azimuths round the horizon, the true or astronomical bearings of the distant objects employed being obtained by an altitude azimuth instrument or theodolite of suitable size and telescopic power.

The observations on the west coast of Scotland were made by Captain (now Admiral) OTTER with an ADIE's Variation Instrument, in which three separate reversible needles were employed. The remaining declinations recorded, to which the observers names are appended, have received equal care in their determination with those above described.

With the exception of a few stations, chiefly on the west coast of Scotland, for which the true or astronomical meridian had been furnished to the Admiralty Surveyors from the Ordnance Survey Office at Southampton, the astronomical meridian to which all the magnetic bearings were referred by the several observers was generally determined in the following manner.

With an azimuth and altitude instrument or the large class of theodolite employed in the Admiralty Coast Surveys (with azimuth circles of 5 to 6 inches diameter),—the zero of which was set to some well-defined object,—the sun's exact altitude, together with the time of its centre passing the middle wire of the telescope, were noted, as also the reading of the azimuthal circle. With the exact latitude and longitude as obtained from data furnished by the Ordnance Survey Office, the sun's astronomical bearing and also that of the zero-point of the instrument, together with the terrestrial object to which it was directed, were thus derived, by two separate methods, from well-known formulæ. Azimuthal angles were then measured from the zero object to five or six well-defined landmarks, equally distributed, where possible, round the horizon; and these angles being referred to the astronomical bearing of the zero object, the astronomical bearings of the several landmarks from the instrument were thus known.

The azimuth compass was now placed in the exact position of the azimuth and altitude instrument, and its sight-vanes directed successively to the several landmarks round the horizon, and their magnetic bearings observed, the mean value of the several differences between the magnetical and astronomical bearings being taken for the magnetic declination [or variation of the compass] at the station.

The observations have been finally reduced to the 1st January, 1872. For this purpose an arbitrary value (an assumed average free from diurnal change) has been assigned for the magnetic declination at Greenwich Observatory for that date, namely 19° 40′ W. The differences between this assigned value and the recorded declination at Greenwich Observatory at the exact time* when the several observations were made on the coasts have been applied to the latter as corrections, and will be found detailed in the tabular

* The Greenwich Magnetical Observations are published to 1868, and from this source the corrections to that date have been obtained. For subsequent comparative values I am indebted to the Astronomer Royal and Mr. GLAISHER, F.R.S., in charge of the Magnetic Department.

abstract as the secular change. These corrections, though not strictly accurate, as will be hereafter seen, from the unequal values of the annual changes of the magnetic declination on the several coasts of the United Kingdom, are nevertheless far within the limits of the probable errors of the observations themselves, and may therefore, I apprehend, be safely adopted as bringing the several observations forward to one common epoch, as well as clearing them from diurnal and other inequalities.

The results thus brought to one epoch were placed on a Mercator's Chart of the British Islands, and the lines of equal declination for each degree graphically drawn through the several values. In this delineation of the lines of equal value I was greatly assisted, both in the determination of their direction and the slight amount of necessary curvature, by numerous observations of the magnetic declination made in neighbouring countries and in the adjacent seas extending to the Arctic Ocean, which cannot be introduced in the appended Chart, but which had been used in the preparation of a Magnetic Variation Chart of the World, published by the Admiralty in 1871.

The procedure here adopted is, under the conditions of so extended an area and limited number of observations, perhaps better adapted for a truthful representation of the Isogonic lines than their calculation according to the usual method, where the differences of the values of the magnetic elements are linear functions of the differences of latitude and longitude, and accordingly straight lines.

From the records of the fixed Magnetic Observatories in this and adjacent countries, it is now certain that the annual change, *i. e.* a decrease of westerly declination, is gradually accelerating, and in some localities notably so within the last ten or fifteen years:—

At Brussels*, between 1850 and 1860, the mean annual decrease was 5′·38; between 1860 and 1868 it was 8′·17.

In Norway, at Christiania†,

between 1850	and	1855	the annual decrease	=	′ 8·45
1855	,,	1860	,,	=	9·48
1860	,,	1865	,,	=	10·52

At Paris‡,

between 1825	and	1858	,,	=	5·0
1858	,,	1868·7	,,	=	9·6

The annual change of the Westerly Declination at the well-known Magnetic Obser-

* See 'Notices Extraites de l'Annuaire de l'Observatoire Royal de Bruxelles' for 1869, by the Director, A. Quetelet, from which the following is extracted for the purpose of the text:—

	h		° ′	Annual change. ′ ′
1850, 12th April,	$10\frac{1}{2}$ A.M.,	observed W. Declination	20 25·7	53·8=5·38
1860, 4th ,,	$1\frac{1}{4}$ P.M.	,, ,,	19 31·9	
1868, 1st ,,	Noon	,, ,,	18 26·5	65·4=8·17

† See 'Notices Extraites de l'Annuaire de l'Observatoire Royal de Bruxelles' for 1864, in a letter from M. Hansteen to M. A. Quetelet.

‡ See Phil. Trans. for 1870, p. 47, "Magnetic Survey of West of France," by the Rev. S. J. Perry.

vatories of Greenwich, Kew, and Stonyhurst College in recent years will be seen from the following abstract. The determinations at Greenwich have been extracted from communications of the Astronomer Royal,—those prior to 1858 from contributions to the Nautical Magazine; subsequent to that year from the Greenwich Magnetical Observations and the Annual Reports made to the Board of Visitors.

The Kew results have been obtained through the kindness of the Observatory Superintendent, SAMUEL JEFFERY, Esq.; and those from Stonyhurst College from the Meteorological and Magnetical Observations published annually.

Greenwich Observatory. Lat. 51° 28′ 38″ N. Long. $0^h\ 0^m\ 0^s$.

	Mean Westerly declination. ° ′	Difference. ′		Annual decrease. ′
1842	23 14·5			
1850	22 24·3	50·2	=	6·27
1855	21 48·0	36·3	=	7·26
1860	21 14·3	33·7	=	6·74
1865	20 32·7	41·6	=	8·32
1871	19 45·0	47·7	=	7·95

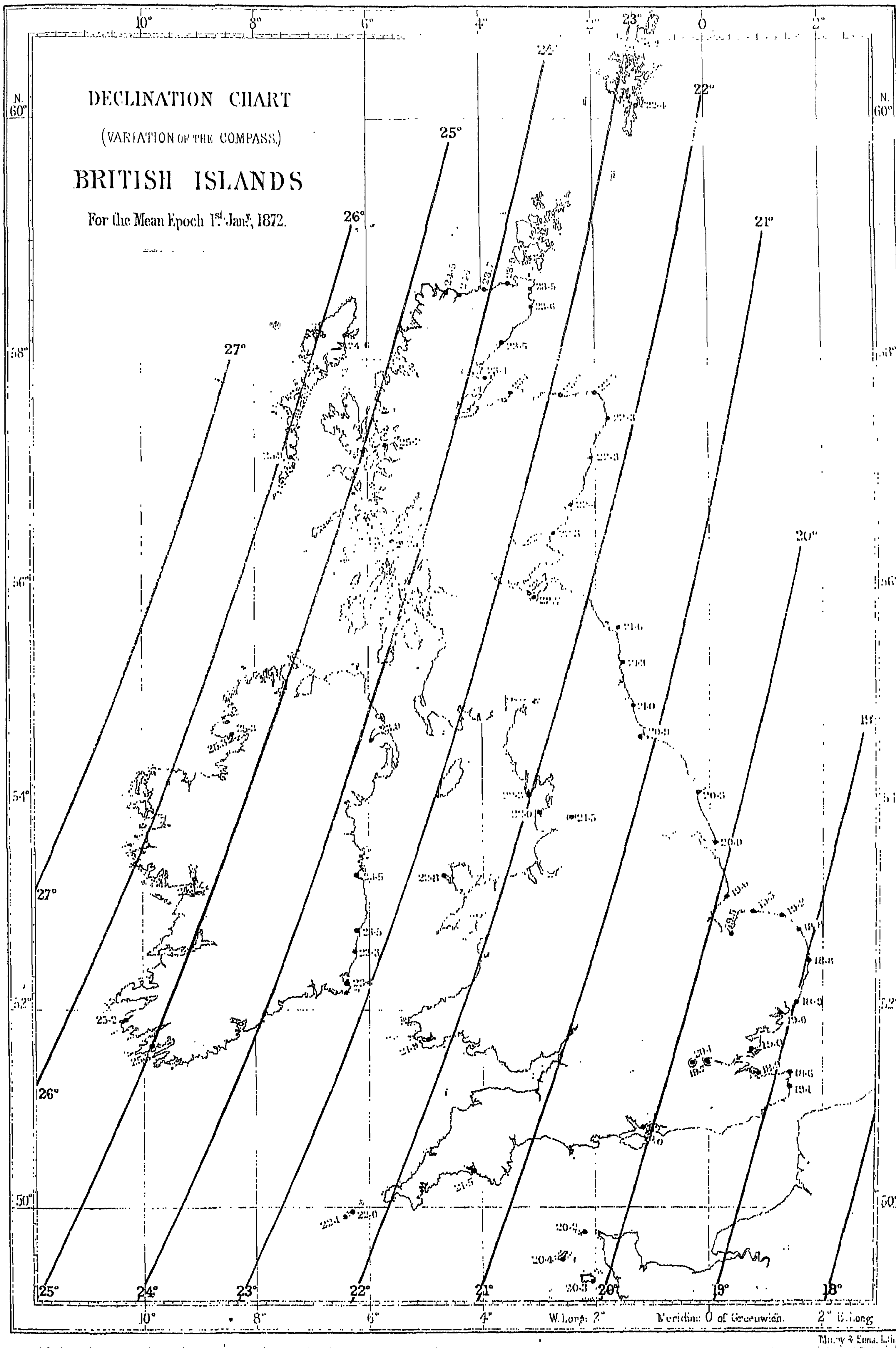
Kew Observatory. Lat. 51° 28′ 6″ N. Long. 0° 18′ 47″ W.

	Mean Westerly declination. ° ′	Difference. ′		Annual decrease. ′
1858	21 54·1			
1860	21 39·9	14·2	=	7·10
1865	20 50·0	40·9	=	8·18
1871	20 10·5	48·5	=	8·08

Stonyhurst College Observatory. Lat. 53° 50′ 40″ N. Long. 2° 28′ 8″ W.

The observations in my possession made at this Observatory do not extend further back than 1865; as the Declination is observed monthly under nearly similar conditions in each year, I have preferred adopting the comparative monthly results for 1865 and 1871, to the mean annual values for those years as appended to the Observatory Reports.

		° ′	Difference. ′		Annual decrease. ′	Mean value. ′
1865 and 1871.	January	22 31·4 21 48·1	43·3	=	7·22	7·71
	February	22 31·2 21 59·3	31·9	=	5·32	
	March	22 22·5 21 38·1	44·4	=	7·40	
	April	22 16·4 21 35·6	40·8	=	6·80	
	May	22 21·2 21 37·3	43·9	=	7·32	
	June	22 18·7 21 37·3	41·4	=	6·90	
	July	22 21·1 21 23·6	60·5	=	10·08	
	August	22 19·2 21 37·5	41·7	=	6·95	
	September	22 30·3 21 35·7	54·6	=	9·10	
	October	22 23·0 21 35·5	47·5	=	7·92	
	November	22 27·5 21 32·5	55·0	=	9·17	
	December	22 21·2 21 31·5	49·7	=	8·28	


DECLINATION CHART
(VARIATION OF THE COMPASS.)
BRITISH ISLANDS
For the Mean Epoch 1st Jany, 1872.
W. Long. 2°
Meridian 0 of Greenwich.
2° E. Long.

The accordance in the values of the annual change for the interval 1865–71 at the three observatories is very satisfactory.

Greenwich	. . . . . .	7·95
Kew	. . . .	8·08
Stonyhurst	. . . . .	7·71

From former investigations on this subject of the secular change of magnetic declination* I was induced to consider that in the area included by the shores of the United Kingdom, the change was greater on its eastern than on its western side. A comparison of the lines of equal declination, as given on the annexed Chart (Plate XLVI.) for the Epoch January 1, 1872, with those given in the Phil. Trans. of 1870 for the Epoch 1842·5, by General Sir EDWARD SABINE, late President of the RoyalSociety, confirms the opinion I had entertained, as also that in the higher parallels of latitude of this area the change is greater than in the lower,—thus incidentally confirming the larger values found at Christiania by M. HANSTEEN as compared with those observed at Brussels by M. QUETELET.

I have appended the details of this comparison of the lines of equal declination for the Epochs 1842·5 and 1872; but the following abstract brings more clearly to view the general character of the changes in the several geographical limits during the past thirty (29·5) years:—

	Annual decrease.
Shetland Islands and N.E. coasts of Scotland, between 60th and 56th parallels	8·24
East coast of England, 56th and 51st parallels	7·78
South coast of England, 51st and 49th parallels. [Dungeness to Scilly, with the Channel Islands.]	7·34
Greenwich Observatory	7·27
Irish Channel, between 52nd and 54th parallels	7·10
Ireland, S.W., West, and N.W. coasts, 52nd to 55th parallels	6·26
Hebrides and West coast of Scotland, 56th to 58th parallels	6·85

Included in the Stations given in this paper at which the magnetic declination has been observed within the last six years, are several at which observations had been previously made either by Mr. WELSH in his Magnetic Survey of Scotland, 1857–58 (see Report of the British Association for the Advancement of Science, 1859), and which are reduced by corresponding observations at Kew to 1st January, 1858, or by Surveying Officers of H.M. Navy (see Report of the British Association for 1861, pp. 273–278), which observations are reduced to the 1st January, 1857, by similar corresponding Kew observations.

We are thus enabled to obtain an approximate value of the amount of annual change for widely diverse localities in the United Kingdom, and to further test the recent acceleration observed at Greenwich and Kew.

* See Declination Map, British Islands, for the mean Epoch of 1st January, 1857, in Report on the Repetition of the Magnetic Survey of England (Report of the British Association for the Advancement of Science, 1861).

As the recent observations available for this purpose were made between the years 1866 and 1870, it was not desirable, on account of the large interval between those years and the Epoch adopted throughout (1872), to employ the results for that Epoch; each observation has therefore been corrected by an amount which would reduce the declination to a mean value for the month of the date actually observed; this correction has been obtained from the Greenwich Observatory Magnetical Tables for 1868, pages iv & v, by taking the differences between the mean Westerly declination in each month as deduced from the mean of the mean Hourly declination (Table III.), from the mean Monthly determination of the Westerly declination at every hour of the day, Greenwich mean solar time (Table II.)*.

* For the British Islands, with the present average amount of Annual change (eight to ten minutes), these will be found useful Tables to obtain the mean value of the magnetic declination for the month when observed at any hour of the day.

The following Table, which is deduced from Tables II. and III. alluded to in the text, has been constructed as it presents at sight the required correction, *i. e.* the amount in minutes of arc to be applied to the Westerly declination as observed within the limits of the British Islands at any hour of the day, Greenwich mean solar time, in order to obtain the mean value of the Westerly declination for the month. + sign denotes the amount in excess above the mean monthly value, and must be subtracted from the observed declination; − sign the amount in defect, and therefore to be added to the observed declination.

Greenwich mean solar time.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Greenwich mean solar time.
h	′	′	′	′	′	′	′	′	′	′	′	′	h
0	+2·0	+2·8	+4·6	+5·9	+5·0	+4·4	+4·6	+6·2	+6·8	+5·4	+3·6	+3·1	0
1	+2·8	+3·8	+6·4	+8·0	+6·0	+5·5	+6·1	+7·5	+6·6	+5·9	+4·1	+3·5	1
2	+2·4	+4·1	+6·3	+7·8	+5·4	+5·9	+6·5	+7·0	+5·9	+5·1	+3·2	+3·4	2
3	+1·6	+3·4	+4·9	+5·5	+4·4	+5·1	+5·9	+5·5	+3·7	+4·0	+2·1	+2·8	3
4	+0·8	+2·0	+3·2	+3·5	+2·9	+4·4	+4·8	+2·8	+2·2	+2·0	+1·3	+2·3	4
5	+0·6	+0·6	+0·6	+1·7	+1·8	+3·1	+3·1	+1·3	0·0	+0·6	+0·7	+1·3	5
6	+0·5	+0·1	−0·1	+0·5	+0·7	+1·9	+1·5	+0·3	−0·8	−0·2	+0·1	+0·3	6
7	−0·1	−0·3	−0·6	−0·3	−0·1	+0·3	+0·2	−0·3	−1·0	+0·1	−0·4	−0·2	7
8	−0·5	−0·6	−1·4	−0·6	−0·7	−0·6	−0·3	−0·9	−2·4	−1·7	−0·9	−1·5	8
9	−1·9	−2·3	−2·1	−1·1	−1·0	−0·2	−1·1	−1·2	−2·1	−2·3	−2·2	−2·2	9
10	−2·9	−2·9	−1·5	−1·7	−1·1	−0·8	−1·4	−2·4	−2·3	−2·5	−2·8	−2·4	10
11	−2·4	−3·3	−1·4	−1·9	−2·0	−1·4	−1·4	−2·5	−2·4	−2·4	−2·4	−2·2	11
12	−2·0	−3·1	−1·3	−2·6	−1·9	−1·8	−1·6	−2·1	−2·2	−2·6	−1·9	−2·1	12
13	−1·1	−1·9	−1·6	−2·9	−1·9	−1·4	−2·3	−1·9	−2·2	−2·2	−1·6	−1·9	13
14	−0·7	−1·4	−2·0	−3·2	−2·3	−2·1	−2·9	−1·4	−1·8	−1·9	−1·3	−1·4	14
15	−0·2	−1·2	−3·1	−3·1	−2·4	−2·1	−2·7	−2·2	−1·7	−1·1	−1·0	−1·2	15
16	−0·5	−0·9	−2·3	−2·2	−2·7	−3·0	−3·4	−2·5	−1·8	−1·5	−0·4	−1·1	16
17	+0·1	−0·2	−1·7	−2·0	−2·6	−3·7	−4·0	−3·3	−2·1	−1·0	−0·8	−1·2	17
18	+0·1	+0·3	−1·4	−2·7	−3·1	−3·9	−4·2	−3·9	−1·8	−0·9	−0·9	−0·7	18
19	0·0	+0·2	−1·5	−3·8	−3·2	−4·1	−3·8	−4·2	−2·0	−1·5	−0·6	−0·4	19
20	−0·1	−0·9	−2·7	−4·4	−3·3	−3·9	−3·4	−3·4	−2·0	−2·2	−0·9	−0·4	20
21	−0·4	−1·0	−2·7	−3·1	−1·9	−3·0	−2·4	−2·0	−1·0	−2·0	−0·5	−0·4	21
22	+0·5	+0·5	−0·7	−0·4	+0·1	−0·4	−0·6	+0·5	+1·1	+0·2	+0·7	+0·3	22
23	+1·4	+2·0	+2·2	+3·0	+2·8	+2·4	+1·6	+3·4	+4·0	+3·1	+2·8	+1·7	23
0	+2·0	+2·8	+4·6	+5·9	+5·0	+4·4	+4·6	+6·2	+6·8	+5·4	+3·6	+3·1	0

				Declination West. ° ′	Diff. ′	Annual change. ′	Mean value of annual change.
Shetland Islands and N.E. Coast of Scotland	Shetland Islands (Lerwick) ...	Welsh	1858·0	25 17·5	150·5	=12·86	11·21
		Calver	1869·7	22 47·0			
	Thurso..............	Otter	1857·0	26 01·0	76·0	= 7·90	
		Calver	1866·6	24 45·0			
	Thurso (*continued*)	Welsh	1858·0	26 30·3	105·3	=12·24	
		Calver	1866·6	24 45·0			
	Wick	Welsh	1858·0	26 03·7	101·7	=11·83	
		Calver	1866·6	24 22·0			
East Coast of England	Bridlington	Ross.........	1857·0	22 43·6	106·6	=	10·35
		Calver	1867·3	20 57·0			
South Coast of England......	Plymouth	Cox	1857·0	23 29·7	80·7	=	7·87
		Mayes	1867·25	22 09·0			
Ireland, S.W. Coast	Berehaven	Church ...	1857·0	26 42·5	34·5	= 3·63	6·58
		Moriarty ...	1866·5	26 08·0			
	Valentia	Edye	1857·0	27 39·0	126·5	= 9·54	
		Kerr.........	1870·25	25 32·5			
Scotland, West and N.W. Coasts*	Oban (Dunolly Hill)...........	Bedford ...	1857·0	27 00·6	67·6	= 6·93	9·55
		Otter	1866·75	25 53·0			
	Oban (Kerrera) ...	Bedford ...	1857·0	26 39·0	97·0	=10·00	
		Otter	1866·7	25 02·0			
	Kyle Akin	Otter	1857·0	27 26·0	86·0	= 9·05	
		Otter	1866·5	26 0·0			
	Loch Eribol	Otter	1857·0	27 11·5	117·5	=12·24	
		Calver	1866·6	25 14·0			

It will be here observed that the proportional amount of change in the several geographical districts agrees with that observed for the longer interval of 29·5 years.

* Stornoway in the Hebrides has not been included, as the stations where the observations were made at the two dates are some distance apart, and much local disturbance exists in the neighbourhood. There appears, indeed, on the western coast of Scotland generally and on many of the outlying islands, to be great difficulty in selecting a position to avoid local disturbances from basaltic and other eruptive rocks. Compass Hill at Canna is a notable example.

Coasts of Scotland.

Stations.	Lat. N.	Long. W.	Date.	Greenwich mean time of observation.	Declination, West. Observed.	Declination, West. Secular change.	Declination, West. Corrected.		Observers.
	° ′	° ′		h m	° ′	′	° ′	° ′	
SHETLAND ISLANDS, Lerwick (near Fort Charlotte)	60 9	1 9	1869, Aug. 30	9 20 A.M.	22 46	21	22 25		Calver.
LOCH ERIBOL, Hoan Island	58 34	4 40	1866, July 25	1 30 P.M.	25 20	50	24 30		"
KYLE OF TONGUE, Rabbit Island	58 32	4 23	" " 25	4 0 P.M.	24 57	49	24 8		"
PORT SKERRA, East Rock	58 34	3 56	" " 25	7 0 P.M.	24 28	48	23 40		"
THURSO, Scrabster, near Quay	58 37	3 32	" " 26	5 0 A.M.	24 41	44	23 57		"
FRESWICK BAY, Skerra Head	58 36	3 3	" " 26	9 0 A.M.	24 12	40	23 32		"
WICK, South Head	58 26	3 4	" " 26	11 35 A.M.	24 25	50	23 35		"
HEMSDALE, near Castle Wall	58 7	3 39	" " 26	7 0 P.M.	24 16	47	23 29		"
TARBET NESS, Wilkie Haven	57 52	3 47	" " 27	8 0 A.M.	24 7	42	23 25		"
BURG HEAD, Coast-Guard Station	57 42	3 30	" " 27	11 30 A.M.	23 53	48	23 5		"
KNOCK HEAD	57 41	2 35	" " 28	8 25 A.M.	23 56	43	23 13		"
FRASERBURGH, near Lighthouse	57 42	2 0	" " 28	4 30 P.M.	23 16	48	22 28		"
PETERHEAD, near South Pier	57 30	1 46	" " 31	8 35 A.M.	23 0	43	22 17		"
ABERDEEN, side of River Dee	57 8	2 5	" Aug. 1	9 0 A.M.	23 7	49	22 18	22 19	"
			" "	8 0 P.M.	23 6	46	22 20		
MONTROSE, near Low Lighthouse	56 42	2 27	" " 3	5 10 P.M.	23 7	45	22 22		"
RIVER TAY, Buddon Ness	56 28	2 45	" Sept. 4	7 45 A.M.	23 0	42	22 18		"
GRANTON, Field near Pier	55 59	3 13	" " 1	4 15 P.M.	23 30	48	22 42	22 42·5	"
			" " 3	9 25 A.M.	23 28	45	22 43		
EDINBURGH, Royal Observatory, Calton Hill	55 57	3 11	1871, October	....	22 46*	2	22 44		
OBAN, D[illegible] Hill	56 25	5 27	1866, Oct. 2	Noon — 4½ P.M.	25 58†	49	25 9		Otter.
K[illegible], Ardi[illegible]ve Hill	56 25	5 30	1866, Aug. 28	0 30 — 4 P.M.	25 7†	48	24 19		"
KYLE AKIN, plot W. of Inn	57 16	5 44	" June 20	1 50 P.M.	26 6†	53	25 13		"
HEBRIDES (SOUTH UIST):									
Loch Boisdale	57 9	7 18	1862, Sept.	0 30 P.M.	26 58†	77	25 41	25 52	"
West Fish Island	57 9	7 18	" "	10 30 A.M.	27 3†	73	25 50		
West Coast Sand hill	57 9	7 22	" " 11	3 30 P.M.	27 17†	73	26 4		
STORNOWAY, Coal Island	58 12	6 23	1869, Sept. 11	10 0 A.M.	24 56	23	24 33		Calver.

* Edinburgh Astronomical Observations, vol. xiii. plate 10.

† By ADIE's Variation Instrument, mean of three needles.

Coasts of England.

Stations.	Lat. N.	Long. W. +E.	Date.	Greenwich mean time of observation.	Declination, West. Observed.	Secular change.	Corrected.		Observers.
	° ′	° ′		h m	° ′	′	° ′		
Holy Island, Ross Links	55 39	1 47	1866, Sept. 6	7 35 A.M.	22 20	43	21 37		Calver.
Warkworth, Coquet R. entrance ...	55 20	1 34	„ „ 6	4 25 P.M.	22 2	45	21 17		„
Sunderland, Roker	54 56	1 22	1867, April 15	8 40 A.M.	21 40	38	21 2		„
Seaton Snook	54 38	1 10	„ „ 17	8 30 A.M.	21 31	39	20 52		„
Bridlington Quay, near S. pier......	54 5	0 12	„ „ 19	8 45 A.M.	20 54	39	20 15		„
Spurn Point	53 35	0 7+	1866, Sept. 18	7 5 A.M.	20 46	46	20 0	19 59	„
			„ „ 24	8 50 A.M.	20 45	43	20 2		
			„ „ 27	5 5 P.M.	20 43	44	19 59		
			1867, May 10	10 0 A.M.	20 40	44	19 56		
Gibraltar Point	53 6	0 19+	„ „ 17	8 0 A.M.	20 16	38	19 38		
Lynn, West side of New Cut	52 45	0 23+	„ „ 25	10 45 A.M.	20 13	43	19 30	19 31	Calver.
			„ „ 27	8 0 A.M.	20 11	39	19 32		
Holkham Bay, on Sand Hill	52 58	0 49+	„ „ 29	7 30 A.M.	20 17	35	19 42	19 40·5	„
			„ „ 29	6 0 P.M.	20 19	40	19 39		
Cromer, near Lighthouse	52 55	1 19+	„ „ 30	6 0 P.M.	19 56	41	19 15	19 14·5	„
			„ „ 31	6 0 A.M.	19 51	37	19 14		
Winterton, on Sand Hill	52 43	1 42+	„ „ 31	5 0 P.M.	19 30	44	18 46	18 49·5	„
			„ June 7	8 0 A.M.	19 29	36	18 53		
Pakefield, on Cliff North of	52 27	1 44+	„ Aug. 30	8 20 A.M.	19 26	40	18 46		„
Orfordness, near High Lighthouse..	52 5	1 34+	„ Sept. 20	9 45 A.M.	19 36	39	18 57	18 57	„
			„ „ 20	4 25 P.M.	19 40	43	18 57		
Harwich, Beacon Cliff..................	51 56	1 17+	„ „ 19	10 0 A.M.	19 39	37	19 02	19 01·5	„
			„ „ 19	5 0 P.M.	19 40	39	19 01		
Burnham, River Crouch	51 37	0 49+	„ „ 25	10 0 A.M.	19 45	42	19 03	19 02·5	„
			„ „ 25	5 45 P.M.	19 39	37	19 02		
Sheppey Island, Shellness	51 22	0 57+	„ „ 26	4 0 P.M.	19 36	41	18 55	18 56	„
			„ „ 27	9 15 A.M.	19 36	39	18 57		
North Foreland, near Obelisk	51 23	1 25+	„ „ 30	4 15 P.M.	19 19	40	18 39	18 38	
			„ Oct. 2	9 0 A.M.	19 18	41	18 37		
Walmer, on beach	51 12	1 24+	1865, July 24	7 20 A.M.	19 59	52	19 07		Evans, Staff Captain, R.N.
Portsmouth, Southsea	50 47	1 5	1866, Dec. 27	3 10 P.M.	20 32	44	19 48	19 59	Mayes, Staff Commander, R.N.
	......	......	1867, July 20	4 25 P.M.	20 24	42	19 42		
Rat Island	50 48	1 6	1871, Sept. 9	5 0 P.M.	20 28	1	20 27		
Channel Islands. Alderney, near Windmill	49 42	2 13	1863, April 23	9 45 A.M.	21 18	66	20 12	20 11·5	J. Richards, Staff Commander, R.N.
			„ „ 24	10 45 A.M.	21 17	71	20 06		
near E. end of Island	......	......	„ „ 23	11 40 A.M.	21 16	70	20 06		
			„ „ 24	....	21 9	72	19 57		
near W. end of Island	49 42	2 14	„ „ 23	10 45 A.M.	21 31	68	20 23		
			„ „ 24	12 15 A.M.	21 37	72	20 25		

Coasts of England (continued).

Stations.	Lat. N.	Long. W.	Date.	Greenwich mean time of observation.	Declination, West.				Observers.
					Observed.	Secular change.	Corrected.		
	° ′	° ′		h m	° ′	′	° ′	° ′	
Channel Islands. Jersey, near Roselle Mill	49 14	2 3	1863, April 16	9 45 A.M.	21 23	70	20 13	20 16	J. Richards, Staff Commander, R.N.
Boulez Guard-house	49 15	2 6	„ „ 16	0 20 P.M.	21 34	75	20 19		
Guernsey, Castle Cornet	49 27	2 32	„ „ 11	10 50 A.M.	21 38	72	20 26	20 24	„
Doyle column	49 26	2 32	„ „ 11	0 35 P.M.	21 36	76	20 20		
Icart Barrack	49 25	2 34	„ „ 13	3 10 P.M.	21 37	71	20 26		
Plymouth, Devonport	50 22	4 10	1866, Nov. 27	3 30 P.M.	22 18	43	21 35	21 28·5	Mayes.
near Keyham Dockyard	50 23	4 11	1867, June 28	8 15 A.M.	21 58	36	21 22		
Scilly Isles, Menewethan	49 57	6 15	1863, July 8	P.M.	23 14	71	22 3	22 01	G. Williams, Captain, R.N.
Great Ganilly	......	......	„ Nov. 9	2 P.M.	23 14	65	22 9		
St. Martin, at daymark	49 58	6 16	„ Aug. 27	P.M.	23 18	70	22 8		
St. Mary, Newfoundland Point	49 55	6 17	„ Sept. 18	P.M.	23 56	70	22 46		
Peninnis Point	49 54	6 18	„ Nov. 12	Noon.	23 17	65	22 12		
Round	49 59	6 19	„ July 7	P.M.	23 6	72	21 54		
			„ Aug. 21	3 P.M.	23 9	71	21 58		
St. Helens	49 58	6 19	„ „ 20	P.M.	22 45	68	21 37		
			„ Nov. 7	P.M.	22 49	64	21 45		
Gugh	49 54	6 20	„ July 10	P.M.	23 15	68	22 7		
St. Agnes, Horse Point	49 53	6 20	„ Sept. 17	11 30 A.M.	22 38	68	21 30		
Oliver's Castle	49 58	6 21	„ Oct. 2	P.M.	22 55	67	21 48	22 03·6	Williams (*continued*).
Samson	49 56	6 21	„ July 10	Noon.	23 26	72	22 14		
Bryer, Watch Hill	49 57	6 21	„ Aug. 24	P.M.	23 22	69	22 13		
Shipman Head	49 58	6 22	„ Sept. 29	P.M.	23 11	68	22 3		
Annet	49 54	6 22	„ Aug. 14	P.M.	23 7	69	21 58		
			„ Sept. 11	P.M.	23 8	70	21 58		
Meledgan	49 52	6 22	„ Oct. 22	3 30 P.M.	23 24	66	22 18		
Minicarlo	49 56	6 23	„ Nov. 13	11 A.M.	22 52	64	21 48		
Gorregen	49 52	6 23	„ Oct. 17	3 15 P.M.	23 6	63	22 3		
Rosevear	49 52	6 24	„ „ 17	11 A.M.	23 21	65	22 16		
Crebawethan	49 53	6 25	„ „ 17	1 P.M.	23 13	72	22 1		
Milford Haven:									
near Llanstadwell Church	51 42	4 58	1866, Dec. 20	1 30 P.M.	22 57	44	22 13	21 57	E. J. Bedford, Captain, R.N.
Mount Pleasant	51 41	4 57	„ „ 19	Noon.	22 26	45	21 41		„
Neyland	51 42	4 55	1871, Oct. 24	Noon.	22 8	11	21 57		J. Richards.
Holyhead	53 19	4 37	„ Aug. 10	3 45 P.M.	22 58	7	22 51		„
Fleetwood, Low Lighthouse	53 56	3 1	„ „ 11	4 0 P.M.	22 8	7	22 01		„
Walney Island, Lighthouse	54 3	3 10	„ May 23	8 45 A.M.	22 20	3	22 17		„
Stonyhurst Magnetic Observatory	53 51	2 28	1872 (1° 49′ difference from Greenwich)*				21 29		
Kew Magnetic Observatory	51 28	0 19	1872 (0° 25′ difference from Greenwich)†				20 05		

* Mean of 7 years' comparison. † Mean of 14 years' comparison.

Coasts of Ireland.

Stations.	Lat. N.	Long. W.	Date.	Greenwich mean time of observation.	Declination, West. Observed.	Secular change.	Corrected.		Observers.
	° ′	° ′		h m	° ′	′	° ′		
BELFAST, near Abercorn Basin	54 36	5 55	1869, July 16	9 55 A.M.	24 15	22	23 53		Calver.
KINGSTON, Harbour, North pier	53 18	6 7	1871, Aug. 8	3 30 P.M.	23 31	4	23 27		J. Richards.
ARKLOW, Ovoca River (entrance)	52 47	6 9	" " 5	4 10 P.M.	23 38	8	23 30		"
CAHORE POINT	52 34	6 12	" July 26	3 40 P.M.	23 21	5	23 16		"
WEXFORD, South Bay, Carnsore cliff ...	52 15	6 20	" " 31	6 50 A.M.	23 17	+8	23 25		"
BEREHAVEN:									
Dinish Island, highest part	51 39	9 51	1866, July 9	6 35 P.M.	26 09	50	25 19	25 16	Moriarty, Staff Captain, R.N.
Bere Island, Palmer Point	51 39	9 47	" " 11	5 50 A.M.	25 59	46	25 13		
VALENTIA, Meteorological Observatory.	51 55	10 18	1868, Oct. 23–27	A.M. & P.M.	25 52	31	25 21	25 13·5	Rev. T. Kerr.
			1871, Sept. 18–30	"	25 13	7	25 6		
GALWAY, on Green near Dock...........	53 16	9 3	1869, May 26	10 15 A.M.	25 18	25	24 53	24 56	Calver.
			" June 9	4 0 P.M.	25 28	29	24 59		
KILLIBEGS, Rough Point................	54 38	8 26	" " 23	10 20 A.M.	25 42	26	25 16	25 17	"
			" " 26	7 20 P.M.	25 41	23	25 18		

Annual change of Westerly Declination on coasts of United Kingdom between the Epochs 1842·5 and 1872 [29·5 years], obtained by comparison with Sir EDWARD SABINE's Declination Map in Philosophical Transactions for 1870.

Region	Station	Epoch	°	Diff. °	Annual decrease. ′	Mean value.
Shetland Islands and N.E. Coasts of Scotland, between 60th and 56th parallels.	Lerwick	1842·5	27·20	4·45	= 9·06	8·24
		1872·0	22·75			
	Wick	1842·5	27·40	3·90	= 7·93	
		1872·0	23·50			
	Peterhead	1842·5	26·35	4·00	= 8·14	
		1872·0	22·35			
	St. Abbs	1842·5	25·85	3·85	= 7·83	
		1872·0	22·00			
East Coast of England, between 56th and 51st parallels.	Holy Island.........	1842·5	25·50	3·85	= 7·83	7·78
		1872·0	21·65			
	Flamboro' Head ...	1842·5	24·20	3·80	= 7·73	
		1872·0	20·40			
	Cromer	1842·5	23·10	3·80	= 7·73	
		1872·0	19·30			
	North Foreland ...	1842·5	22·65	3·80	= 7·73	
		1872·0	18·85			

Annual change of Westerly Declination (continued).

Region	Station	Year	°	Diff. °		Annual decrease. ′	Mean value. ′
South Coast of England, from Dungeness to Scilly, including Channel Islands, between 51st and 49th parallels.	Dungeness	1842·5	22·75	3·75	=	7·63	7·34
		1872·0	19·00				
	Portsmouth	1842·5	23·70	3·65	=	7·43	
		1872·0	20·05				
	Guernsey	1842·5	24·00	3·60	=	7·33	
		1872·0	20·40				
	Plymouth	1842·5	24·95	3·55	=	7·22	
		1872·0	21·40				
	Scilly Islands	1842·5	25·80	3·50	=	7·12	
		1872·0	22·30				
Irish Channel, between 52nd and 54th parallels.	Milford	1842·5	25·75	3·50	=	7·12	7·10
		1872·0	22·25				
	Wexford	1842·5	26·65	3·40	=	6·91	
		1872·0	23·25				
	Dublin	1842·5	27·00	3·45	=	7·02	
		1872·0	23·55				
	Holyhead	1842·5	26·20	3·55	=	7·22	
		1872·0	22·65				
	Calf of Man	1842·5	26·55	3·55	=	7·22	
		1872·0	23·00				
	Cantyre (Mull)	1842·5	27·50	3·50	=	7·12	
		1872·0	24·00				
Ireland, S.W., West, and N.W. Coasts: 52nd to 55th parallel.	Martin Head	1842·5	28·30	3·25	=	6·61	6·26
		1872·0	25·05				
	Sligo	1842·5	28·35	3·05	=	6·20	
		1872·0	25·30				
	Galway	1842·5	28·25	3·00	=	6·10	
		1872·0	25·25				
	Valentia	1842·5	28·30	2·95	=	6·00	
		1872·0	25·35				
	Cork	1842·5	27·50	3·15	=	6·40	
		1872·0	24·35				
Hebrides and West Coast of Scotland: 56th to 58th parallel.	West Coast of Islay	1842·5	28·00	3·40	=	6·91	6·85
		1872·0	24·60				
	Kyle Akin	1842·5	28·25	3·50	=	7·12	
		1872·0	24·75				
	West Coast, Outer Hebrides	1842·5	29·40	3·20	=	6·51	
		1872·0	26·20				

XV. *On the Specific Heat and other Physical Characters of Mixtures of Methylic Alcohol and Water, and on certain relations existing between the Specific Heat of a Mixture or Solution and the Heat evolved or absorbed in their formation. By* A. DUPRÉ, *Ph.D., Lecturer on Chemistry at Westminster Hospital. Communicated by* WILLIAM ODLING, *M.B.*

Received April 4,—Read May 16, 1872.

THE pure methylic alcohol was prepared according to the following process, devised by Mr. CHAPMAN. Rectified wood-spirit is mixed with its own bulk of a saturated solution of calcium chloride, the mixture is heated to boiling and allowed to stand over night. The layer of oil found floating on the surface is carefully removed, and the fluid underneath is mixed with about one volume per cent. of a saturated solution of lead acetate. An amount of sulphide of ammonium, not quite sufficient to precipitate all the lead, is next added, the precipitate, which carries down much colouring-matter and many minute globules of oil, is filtered off, or allowed to subside, and the clear fluid is distilled. To this distillate caustic soda in coarse powder is added, and after standing some time it is diluted with water and again distilled; much resinous matter is thus removed, and the acetate of methyl is decomposed. The specific gravity of this second distillate is now brought to about ·82 (if necessary, by treatment with potassium carbonate), after which it is mixed with one fourth of its bulk of a saturated solution of bisulphite of ammonium. The mixture is allowed to stand for several days, and is then filtered and distilled from a water-bath; to the distillate a little sulphuric acid is added, and it is then redistilled, also from a water-bath. Finally a slight excess of caustic soda is added, and the liquid is once more distilled, when pure methylic alcohol passes over, which is rendered anhydrous by several distillations over caustic lime. The purity of the spirit is tested by oxidizing 20 grammes of it with an excess of bichromate of potassium and sulphuric acid, when it should yield nothing but carbonic acid and water.

The spirit thus prepared was perfectly miscible with water in every proportion; it had at 10° C. a specific gravity of ·81371, boiled at 58°·6 C. at a pressure of 757·4 millims., and had a specific heat of 58·325 between the temperatures of 60° and 18°.

SECTION I.—*Specific Heat.*

The mixture*, the specific heat of which is to be estimated, is enclosed in a small annular brass vessel, which can be closed hermetically by means of a screw-plug. In the inner cylindrical space a fan-wheel is fixed, acting as a stirrer when the vessel is

* For the method employed for the preparation of mixtures of the exact strength desired, see Section V.

rotated under water. This vessel, when filled, is heated in a REGNAULT'S steam-oven by the vapour of methylic alcohol; and when the temperature has become constant it is lowered into the calorimeter, hooked on to a wire, and made to spin round underneath the surface of the water; a second observer meanwhile watches the thermometer of the calorimeter. The temperature of this rises, rapidly at first, more slowly towards the end, and reaches a maximum in from two to three minutes. The thermometer is observed during the next succeeding 1 to $1\frac{1}{2}$ minute, and the fall observed is added as a correction to the highest temperature reached. The results obtained are not quite as concordant as those yielded by the method chiefly employed in estimating the specific heat of mixtures of ethylic alcohol and water (Philosophical Transactions, 1869, p. 591), owing principally to the difficulty of keeping the temperature of the steam-oven constant for a sufficient length of time when the vapour of methylic alcohol, instead of steam, is used for heating. Methylic alcohol has, however, too low a boiling-point for the successful application of the former method.

From the data obtained the specific heat of the mixture is calculated by help of the following formula:—

$$\frac{C}{100}=\frac{W(t''-t)}{m(T-t')}-\frac{\mu}{m},$$

wherein C is the specific heat sought,

W the water value of calorimeter and contents (water, thermometer, and calorimeter itself),

t temperature of calorimeter at the beginning,

t'' temperature of calorimeter at end, correction added,

T temperature of steam-oven,

m weight of mixture employed,

μ water value of annular brass vessel,

t' temperature of calorimeter at end, without correction.

In the following Table the experiments marked with an asterisk were made with methylic alcohol of one preparation, those not so marked with spirit of another preparation.

TABLE I.

Amount of water in calorimeter 1156·666 grms.

Water value of calorimeter 8·565 grms.

Water value of annular brass vessel (μ) was 6·8337 grms. in all experiments with an asterisk, and 6·6572 grms. in the others.

Water value of immersed part of thermometer 1·139.

Time occupied in each experiment, 3 to $4\frac{1}{2}$ minutes.

Spirit 10 per cent.

Experiment.	*m.*	*t'''* †.	T.	*t.*	*t.*	V‡.	*t''.*	C.
1.	52·140	12·7	52·65	11·003	12·965	0·000	12·965	97·828
2.	52·140	13·5	53·15	11·980	13·940	0·000	13·940	99·054
3*.	54·351	20·8	62·80	19·042	21·174	0·014	21·188	98·062
4*.	54·111	20·8	62·45	18·283	20·456	0·014	20·470	99·387

Mean specific heat of spirit of 10 per cent. 98·582.

Spirit 20 per cent.

Experiment.	*m.*	*t'''.*	T.	*t.*	*t'.*	V.	*t''.*	C.
5.	49·735	13·5	53·75	12·556	14·380	0·000	14·380	95·266
6.	49·735	14·7	55·15	13·728	15·589	0·000	15·589	96·935
7.	49·735	16·0	58·15	13·880	15·860	0·000	15·860	96·415
8*.	51·831	19·6	60·60	18·839	20·740	0·016	20·756	95·045

Mean specific heat of spirit of 20 per cent. 95·914.

Spirit 30 per cent.

Experiment.	*m.*	*t'''.*	T.	*t.*	*t'*	V.	*t''.*	C.
9.	51·390	11·0	55·62	10·296	12·279	0·010	12·289	91·413
10.	51·390	10·0	54·52	9·968	11·925	0·010	11·935	91·856
11*.	51·151	19·0	59·8	17·101	19·017	0·000	19·017	93·768
12*.	50·831	19·3	61·15	18·617	20·484	0·030	20·514	93·595

Mean specific heat of spirit of 30 per cent. 92·658.

Spirit 40 per cent.

Experiment.	*m.*	*t'''.*	T.	*t.*	*t'.*	V.	*t''.*	C.
13.	51·383	13·0	52·90	11·960	13·718	0·000	13·718	88·891
14.	51·115	15·0	52·80	12·703	14·412	0·000	14·412	88·410
15*.	50·0[illegible]	17·3	61·54	17·079	18·963	0·005	18·968	89·784
16*.	49·580	19·9	60·39	18·850	20·598	0·006	20·604	89·793

Mean specific heat of spirit of 40 per cent. 89·219.

Spirit 50 per cent.

Experiment.	*m.*	*t'''.*	T.	*t.*	*t'.*	V.	*t''.*	C.
17.	49·890	10·2	56·48	10·056	11·874	0·010	11·884	82·456
18.	50·220	13·0	50·90	11·601	13·203	0·000	13·203	85·443
19*.	49·491	21·0	60·95	19·840	21·494	0·000	21·494	84·867
20*.	49·281	21·0	61·00	19·605	21·278	0·000	21·278	85·817

Mean specific heat of spirit of 50 per cent. 84·645.

† *t'''*, temperature of air. ‡ V, correction added.

Spirit 60 per cent.

Experiment.	*m.*	*t'''.*	T.	*t.*	*t'.*	V.	*t''.*	C.
21.	47·930	12·5	58·85	11·379	13·137	0·010	13·147	80·228
22.	47·834	13·0	55·90	11·415	13·072	0·000	13·072	80·432
23*.	48·471	21·0	61·30	20·006	21·558	0·000	21·558	79·873

Mean specific heat of spirit of 60 per cent. 80·177.

Spirit 70 per cent.

Experiment.	*m.*	*t'''.*	T.	*t.*	*t'.*	V.	*t''.*	C.
24.	46·980	12·0	56·15	11·489	13·046	0·010	13·056	75·567
25.	46·980	11·5	56·65	10·092	11·704	0·000	11·704	74·872
26*.	45·921	18·4	60·18	17·087	18·560	0·005	18·565	75·491
27*.	45·311	19·1	58·10	18·020	19·383	0·008	19·391	76·071

Mean specific heat of spirit of 70 per cent. 75·500.

Spirit 80 per cent.

Experiment.	*m.*	*t'''.*	T.	*t.*	*t'.*	V.	*t''.*	
28.	44·180	11·1	55·65	10·335	11·756	0·000	11·756	70·399
29.	44·180	11·7	58·15	11·240	12·713	0·005	12·718	70·818
30*.	45·621	21·1	58·50	20·296	21·520	0·000	21·520	69·643
31*.	44·601	21·1	59·90	20·074	21·320	0·000	21·320	

Mean specific heat of spirit of 80 per cent. 69·999.

Spirit 90 per cent.

Experiment.	*m.*	*t'''.*	T.	*t.*	*t'.*	V.	*t''.*	C.
32.	43·660	11·0	58·48	9·965	11·385	0·000	11·385	65·303
33*.	44·156	21·4	60·45	20·352	21·520	0·000	21·520	63·770
34*.	42·681	......	59·20	16·981	18·187	0·000	18·187	64·346
35*.	42·016	21·0	62·20	20·130	21·294	0·014	21·308	63·706

Mean specific heat of spirit of 90 per cent. 64·282.

Spirit 100 per cent.

Experiment.	*m.*	*t'''.*	T.	*t.*	*t'.*	V.	*t''.*	C.
36.	43·029	13·0	58·05	11·225	12·465	0·000	12·465	58·264
37.	42·679	13·2	59·65	12·465	13·695	0·000	13·695	57·548
38.	42·429	14·1	60·75	13·289	14·545	0·000	14·545	59·036
39*.	42·586	17·9	51·20	17·067	17·969	0·004	17·973	58·625
40*.	42·116	18·0	59·60	17·082	18·199	0·000	18·199	58·494
41*.	41·341	18·1	59·70	17·540	18·619	0·006	18·625	57·985

Mean specific heat of absolute methylic alcohol 58·325.

TABLE II.

Per cent., by weight, of absolute methylic alcohol.	Specific heat found.	Specific heat calculated.	Difference.
10	98·582	95·832	+2·750
20	95·914	91·665	4·249
30	92·658	87·497	5·161
40	89·219	83·330	5·889
50	84·645	79·162	5·483
60	80·177	74·995	5·182
70	75·500	70·827	4·673
80	69·999	66·660	3·339
90	64·282	62·492	1·790
100	58·325		

SECTION II.—*Heat produced by the mixing of Methylic Alcohol and Water.*

The amount of heat produced is estimated as follows:—An annular vessel made of thin brass, such as described in the section Specific Heat, and capable of holding about 100 cub. centims., is immersed in the water of the calorimeter. The vessel has two openings provided with short tubes, which reach above the surface of the water when the whole body of the vessel is submerged. Through one of these tubes passes tightly a rod connected with an efficient stirrer moving up and down the annular space; the other tube carries a small glass funnel which can be closed by a stopper. The experiment is conducted as follows:—One of the two liquids is weighed out in the brass vessel, the other is weighed out in a thin glass bulb, the quantity of liquid remaining in the bulb when it is emptied, and that which adheres to the sides of the small funnel, which experience had shown to be a very constant quantity, being allowed for, so that the exact amount of liquid necessary is delivered into the brass vessel. The brass vessel is now fixed in its proper position in the calorimeter, which is then filled with water a little below the temperature of the room; and the glass bulb containing the other liquid is also immersed in the calorimeter. After the lapse of fifteen minutes, the water in the calorimeter having been stirred from time to time, the temperature of the various fluids has become equalized. The glass bulb is now taken out without touching it with the hand, and its contents are poured rapidly through the funnel into the brass vessel; the funnel is closed, and the two fluids in the brass vessel thoroughly mixed by means of the stirrer. The temperature of the water in the calorimeter, which is constantly stirred, reaches a maximum in from 4 to 5 minutes; it is observed during 2 or $2\frac{1}{2}$ minutes longer, and any fall observed is added as a correction to the highest temperature reached. As, however, the whole rise is small, this correction usually amounts to very little, and frequently to nothing. From the data thus obtained the heat produced by mixing the liquids in the brass vessel is calculated, the water value of the mixture in the brass vessel being of course added to the water value of the calorimeter and contents.

. TABLE III.

Water value of calorimeter 8·664 grms.
Water value of immersed part of thermometer and stirrer 2·024 grms.
Water value of annular brass vessel 5·362 grms.
Water contained in calorimeter 1156·666 grms.

Quantities taken of		Per cent., by weight, of alcohol in mixture produced.	Temperature of calorimeter at		Loss by radiation.	Corrected rise.	Units of heat evolved by 5 grms. of the mixture.	Mean.
Methylic alcohol.	Water.		Beginning.	End.				
7·850	70·650	10	19·655	19·930	0·000	·275	21·896	20·930
5·984	53·856	10	19·179	19·353	0·020	·194	19·965	
12·428	49·712	20	16·204	16·560	0·004	·360	35·647	37·276
11·350	45·400	20	16·584	16·944	0·000	·360	38·912	
22·434	52·346	30	16·342	16·862	0·004	·523	43·432	44·744
18·590	43·376	30	17·449	17·913	0·000	·464	46·056	
30·786	46·179	40	16·443	17·020	0·004	·577	46·532	45·384
30·636	45·954	40	17·344	17·886	0·000	·546	44·236	
35·406	35·406	50	16·083	16·578	0·000	·495	43·481	44·429
32·112	32·112	50	17·415	17·890	0·000	·475	45·377	
50·141	33·427	60	16·508	17·071	0·000	·563	41·763	41·493
33·030	22·020	60	17·531	17·904	0·000	·373	41·224	
52·120	22·336	70	16·944	17·356	0·000	·412	34·000	34·456
31·950	13·692	70	17·920	18·184	0·000	·264	34·912	
57·435	14·358	80	17·061	17·338	0·010	·287	24·424	22·448
30·464	7·616	80	19·442	19·562	0·010	·130	20·474	
62·325	6·925	90	19·301	19·446	0·008	·153	13·444	13·164
23·498	2·611	90	18·570	18·619	0·008	·057	12·984	

SECTION III.—*Boiling-points.*

For methods and instruments employed in estimating the boiling-points, specific gravity and rate of expansion, and the compressibility* (Sections III., V., and VI.), see the paper "On the Specific Heat and other Physical Characters of Mixtures of Ethylic Alcohol and Water," by A. DUPRÉ, Ph.D., and F. J. M. PAGE, B.Sc., Phil. Trans. 1869, p. 591, Sections III., V., and VI.

Table IV. gives the boiling-points found, the barometer standing at 757·4 millims. The third column gives the boiling-points calculated on the assumption that they are proportional to the weight of the constituents.

* Instead of using an air-pump for forcing air into the apparatus, an iron bottle containing liquid carbonic anhydride was employed. The water in the apparatus being covered with a layer of oil, to prevent absorption of carbonic anhydride, any desired pressure could easily be obtained by simply turning the screw-valve of the iron bottle to the requisite extent and time.

TABLE IV.

Percentage by weight of absolute methylic alcohol.	Boiling-point observed.	Boiling-point calculated.	Difference.
0	99·93		
10	82·57	95·80	13·23
20	75·26	91·76	16·56
30	70·68	87·53	16·85
40	68·31	83·40	15·09
50	67·08	79·26	11·18
60	65·75	75·13	9·38
70	64·65	71·00	6·35
80	63·13	66·87	3·74
90	60·96	62·73	1·77
100	58·60		

SECTION IV.—*Capillary Attraction.*

The capillary attraction is estimated as follows:—A somewhat wide glass cylinder, the rim of which is accurately ground, stands on a metal frame with three levelling-screws, by means of which the rim of the cylinder can be placed perfectly horizontal. On the rim rests a stout metal bar, through which are drilled three holes exactly at right angles to the lower face of the bar, so that a tube or screw fitting into one of these holes will stand vertical when the rim of the cylinder is horizontal. Two of these holes carry capillary tubes; in the third a long fine screw, pointed at both ends, can be screwed up and down. A mark is etched on each capillary tube, and by depressing or raising the tube the liquid under examination is always made to rise exactly to this mark; the influence of any irregularity in the bore of the tube is thus avoided. The experiment is conducted as follows:—The perfectly clean capillary tubes are put into their respective holes in the plate, and this is placed on the levelled rim of the cylinder. The mixture to be examined is poured into the glass, and a small quantity of the liquid is sucked through each of the tubes by means of a suction-tube. The height of the tubes is then adjusted so that the lower part of the menisci just touches the marked point of the tubes. The screw is now carefully screwed down until the point just touches the surface of the liquid in the cylinder; this contact can be made with the utmost nicety. It now only remains to determine the vertical distance between the upper point of the screw and the lowest part of the two menisci in the tubes, when, the total length of the screw being known, the elevation of the liquid in the capillary tubes becomes known. The vertical distances are measured by means of a very excellent cathetometer, which allows the reading of 0·025 millim.

Table V. gives the results obtained.

Column 1 gives the percentage of methylic alcohol by weight.

Columns 2 and 3 give the observed heights of the threads in millims.

Columns 4 and 5 give the heights supposing water stood at 100 millims.

Column 6 gives the mean of columns 4 and 5.

Column 7 gives the length of a column of water equal in weight to the thread of

alcoholic mixture in column 6, and affords, therefore, a measure of the relative strength of the molecular attraction in the various mixtures.

Column 8 gives the heights calculated on the assumption that they will be proportional to the weight of the constituents of each mixture.

Column 9 gives the difference between columns 7 and 8.

The observed heights given are in each case the mean of two closely concordant experiments. The temperature at which the experiments were made was 13°·5 C.

TABLE V.

1. Alcohol per cent.	2. Heights observed.	3.	4. Heights, assuming water [illegible]	5.	6. Mean of columns 4 and 5.	7. Relative molecular attraction.	8. Height calculated.	9. Difference.
	Tube 1.	Tube 2.	Tube 1.	Tube 2.				
0	74·575	51·050	100·000	100·000	100·000	100·000		
10	51·875	35·225	68·645	69·001	68·820	67·818	93·334	−25·416
20	44·400	30·075	58·749	58·912	58·830	57·264	86·667	29·403
30	39·550	26·850	52·332	52·595	52·463	50·381	80·001	29·620
40	36·975	25·000	48·942	48·971	48·947	46·252	73·335	27·083
50	34·925	23·925	46·212	46·865	46·538	43·136	66·668	23·532
60	34·925	23·650	46·212	46·327	46·269	42·170	60·002	17·832
70	34·050	23·125	45·054	45·298	45·176	40·034	53·336	13·302
80	33·270	22·500	44·022	43·973	43·997	37·955	46·669	8·714
90	32·100	21·825	42·474	42·750	42·612	35·671	40·003	4·332
100	30·650	20·850	41·099	40·842	40·970	33·337		

SECTION V.—*Specific Gravity and Rate of Expansion.*

The mixtures are made by accurately weighing out the required quantities of absolute methylic alcohol and water. This is done in two separate flasks, which are afterwards joined together, air-tight, by a short india-rubber tube; and the thorough mixture is effected by repeatedly pouring the fluids from one flask into the other through the tube. In some of the mixtures a considerable rise in temperature takes place; but as the mixing is effected in a closed vessel no loss of alcohol is experienced. The flasks, still kept connected, are allowed to cool; the mixture is put into a bottle, which should not be less than three quarters filled, and the air is exhausted from the bottle. In this state the bottle is allowed to stand over night, by which means the air dissolved in the mixture is got rid of without appreciable loss of spirit.

Table VI. gives the observed specific gravities of the mixtures at the temperatures of 10° and 20° C., water at 4° C., taken as the unit, together with the calculated specific gravities at 10° and the difference between the observed and calculated specific gravities.

Table VII. gives the expansion of 100 volumes of the mixture when heated from 10° to 20° C., calculated from the data of the previous Table. The figures in column 4 are calculated on the assumption that the expansion is proportional to the volumes of the constituents, the contraction taking place on mixing being allowed for.

To facilitate this calculation (as also the compressibility), Table VIII. gives in

columns 2 and 3 the volumes of water and methylic alcohol respectively contained, at a temperature of 10° C., in 100 volumes of a spirit of the strength given in column 1. Columns 4 and 5 give the combined volumes of the two, before and after mixture respectively; and, lastly, column 6 gives the differences between 4 and 5, thus showing the amount of contraction having taken place in the formation of 100 volumes of the various mixtures. The figures in this Table are calculated from those given in Table VI. By help of this Table the numbers contained in column 4, Table VII., have been calculated thus:—

Let w be the volume per cent. of water contained in the mixture at 10° C.,
m the volume per cent. of methylic alcohol present at the same temperature, and
C the amount of contraction which has taken place in the formation of 100 volumes of this mixture at 10° C.,

Then 100 volumes of this mixture at 10° C. would occupy at 20°

$$\frac{w \times 100\cdot154}{100} + \frac{m \times 101\cdot290}{100} - C$$

volumes, on the assumption that the expansion is proportioned to the volumes of the constituents.

The capacity of the specific-gravity bottle employed was at 10° C. = 545·4985 cub. centims., at 20° C. = 545·6585 cub. centims.

This bottle was brought to the exact temperature desired by immersion in a water-bath of special construction, for details of which see Philosophical Transactions, 1869, p. 608.

TABLE VI.

Per cent. of methylic alcohol, by weight.	Specific gravity at 10° C.	Specific gravity at 20° C.	Specific gravity at 10° C., calculated.	Difference.
0	99973	99819		
10	98632	98384	97762	+ 870
20	97478	97080	95622	1856
30	96222	95675	93573	2649
40	94729	94054	91611	3118
50	92991	92205	89727	3264
60	91048	90207	87923	3125
70	88933	88035	86188	2745
80	86598	85655	84520	2078
90	84054	83079	82916	1138
100	81371	80334		

TABLE VII.

Per cent. of methylic alcohol, by weight.	Volume at 10° C.	Volume at 20° C., found.	Volume at 20° C., calculated.	Difference.
0	100	100·154		
10	100	100·252	100·293	−0·041
20	100	100·410	100·429	−0·019
30	100	100·571	100·562	+0·009
40	100	100·718	100·689	+0·029
50	100	100·853	100·809	+0·044
60	100	100·932	100·922	+0·010
70	100	101·019	101·028	−0·009
80	100	101·101	101·124	−0·023
90	100	101·173	101·212	−0·039
100	100	101·290		

TABLE VIII.

1. Per cent., by weight, of absolute methylic alcohol.	2. Volumes of water.	3. Volumes of methylic alcohol.	4. Combined volumes. Before mixture.	5. After mixture.	6. Contraction
10	88·793	12·121	100·914	100	·914
20	78·003	23·985	101·962	„	1·962
30	67·373	35·475	102·848	„	2·848
40	56·852	46·566	103·418	„	3·418
50	46·507	57·139	103·646	„	3·646
60	36·428	67·135	103·563	„	3·563
70	26·687	76·505	103·192	„	3·192
80	17·322	85·139	102·460	„	2·460
90	8·408	92·967	101·374	„	1·374

SECTION VI.—*Compressibility.*

Table IX. gives the compressibility of the various mixtures for the pressure of one atmosphere.

The numbers in column 5 are calculated on the assumption that the compressibility of a mixture is proportional to the volumes of its constituents. To the compressibilities found directly, 0·000002 is always added as a correction for the compressibility of the piézomètre.

TABLE IX.

Weight of water contained in piézomètre at 4° C. 114·9727 grms.
1 millim. of capillary gauge =0·000517173 cub. centim.

Per cent. of methylic alcohol, by weight.	Depression of gauge, in millims. *	Temperature, in degrees Centigrade.	Compressibility for 1 atmosphere.		Difference.
			Found.	Calculated.	
0	10·10	16·8	0·00004741		
10	9·29	16·2	·00004377	0·00005497	−0·00001129
10	9·25	16·8	·00004359		
20	9·28	15·9	·00004372	·00006303	·00001938
20	9·29	16·2	·00004359		
30	9·12	15·3	·00004300	·00007052	·00002763
30	9·07	15·6	·00004278		
40	10·19	17·4	·00004781	·00007758	·00002977
50	10·49	16·5	·00004916	·00008420	·00003504
60	11·88	16·4	·00005541	·00009029	·00003488
70	13·27	15·7	·00006167	·00009586	·00003419
80	16·05	16·3	·00007416	·00010083	·00002667
90	19·80	15·2	·00009103	·00010511	·00001408
100	23·75	15·0	·00010879		

All relations pointed out in the former paper, as existing between the various properties of mixtures of ethylic alcohol and water, find their parallel in the mixtures now under consideration. Certain sets of properties come to a maximum deviation from the calculated mean at the same strength; in some cases the values found are always below, in others always above the calculated mean; and in both mixtures the rate of expansion shows the same singular peculiarity, viz. of being for certain mixtures below, for others above the mean.

Undoubtedly all the various physical characters of mixtures must, to a certain extent, be dependent on each other, and no explanation of the relation existing between any two of them can be received which is not compatible with every other property observed. The relation existing between some of these characters seems, however, to be more intimate and direct than it is between others. Thus in this, as in the previous mixture, the specific heat and the heat evolved during mixture not only come to a maximum deviation from the mean in mixtures of the same strength, but all mixtures evolving the same amount of heat during their formation possess a specific heat elevated to the same amount above the mean; and, moreover, the numerical relation between these two values is the same for mixtures of every degree of strength. Hence, if the heat evolved in the formation of 5 grms. of any of the mixtures be divided by 7·9, the elevation of the specific heat of this particular mixture above its calculated mean value is obtained. Between the boiling-point and the capillary attraction a somewhat similar relation is found. If in this case the observed depression of the capillarity of any mixture below its calculated mean value be divided by 1·9 (the capillarity of pure water taken as 100),

* In the paper on Mixtures of Ethylic Alcohol and Water, previously quoted, the numbers in the corresponding column (column 2, Table XIII.) should be divided by four.

the depression of the boiling-point of this mixture below the mean is obtained. A similar, though less direct relation appears to exist between the compressibility of a mixture and the amount of contraction taking place in its formation. The numerical relation between these two values differs, however, in different mixtures, both being evidently governed by some additional factor. Lastly, it is also worthy of note that the compressibility of weak mixtures of methylic, as well as of ethylic alcohol and water, is less than that of water, rises to that of water at an alcoholic strength of about 30 per cent., and continues greater for all stronger mixtures.

It has been pointed out above that an intimate relation exists between the heat evolved during the formation of a mixture and its specific heat. This relation may be formulated as follows, in accordance with the principles of the mechanical theory of heat, as first pointed out by KIRCHHOFF in 1858 ("Ueber einen Satz der mechanischen Wärmetheorie und einige Anwendungen desselben; von G. KIRCHHOFF," Pogg. Ann. vol. xiii. p. 177). Relation existing between the specific heat of mixtures and the heat evolved during their formation:—

1. The difference between the number of heat-units evolved during the mixing of given weights of two substances at the temperatures t and t' respectively is equal to the difference between the number of heat-units required to raise the mixture, and that required to raise the two constituents taken separately, from the lower to the higher temperature, provided the condition of the mixtures when they have been brought to the same temperature is the same in both cases. Or let U and U′ be the units of heat evolved by mixing x and y at the temperatures t and t' respectively, S, S′, and S″ the specific heat of the mixture z and its constituents x and y respectively, then

$$\mathrm{U} \sim \mathrm{U}' = z \,.\, \mathrm{S}(t'-t) \sim \{x \,.\, \mathrm{S}'(t'-t) + y \,.\, \mathrm{S}''(t'-t)\}.$$

2. If more units of heat are evolved at the higher than at the lower temperature, the specific heat of the resulting mixture will be below the calculated mean; on the other hand, the specific heat of the mixture will be above the calculated mean, if the greater number of heat-units be evolved at the lower temperature.

3. The absorption of a lesser number of heat-units will be of course equivalent to the evolution of a greater number, while the absorption of a greater number will be equivalent to the evolution of a smaller number of heat-units.

Ethylic Alcohol and Water.

In the formation of 5 grms. of a 10 per cent. mixture of ethylic alcohol and water are evolved, at a temperature of

17°·295 C.,	26·68	units of heat.
71·15 C.,	7·97	„ „
Difference	18·71	„ „

To raise 5 grms. of the mixture from 17°·295 C. to 71°·15 requires		278·86 units.
„ 4·5 grms. water through same interval . . .	242·35	
„ 0·5 grm. alcohol „ „ . . .	16·27	
Total for constituents separately	258·62	258·62 „
Difference between mixture and constituents		20·24 „

In the formation of 5 grms. of a 30 per cent. mixture are evolved, at a temperature of

17°·337 C.,	47·98 units.
52·3 C.,	22·16 „
70·9 C.,	10·34 „

To raise 5 grms. of this mixture from

17°·337 to 52°·30 requires 179·36 units,
17·337 to 70·90 „ 274·79 „

To raise 3·5 grms. water from 17°·337 to 53°·30 requires	122·37 units.
„ 1·5 grm. alcohol „ „	31·62 „
Total units required to raise constituents	153·99 „
To raise 3·5 grms. water from 17°·337 to 70°·90 requires	187·47 „
„ 1·5 grm. alcohol „ „	48·55 „
Total units required to raise constituents	236·02 „

47·98 − 22·16 = 25·82 = difference in units of heat evolved.
179·36 − 153·99 = 25·37 = „ „ required.
47·98 − 10·34 = 37·64 = „ „ evolved.
274·79 − 236·02 = 38·77 = „ „ required.

The differences between theory and experiment are, therefore, in the above cases at least, extremely small and quite within the limits of almost unavoidable experimental error.

The number of units of heat evolved during the mixing of ethylic alcohol and water becomes therefore less the higher the temperature at which the mixing takes place. Assuming, then, that the above given formula (No. 1) is correct, it is easy to calculate a temperature at which the mixing of alcohol and water would not be accompanied by evolution of heat. U′ becomes zero when $U = z \, . \, S(t'-t) \sim \{x \, . \, S'(t'-t) + y \, . \, S''(t'-t)\}$.

Let U be the units of heat evolved in the formation of 5 grms. of mixture at the temperature t, then the temperature T, at which no heat is evolved on mixing, will be

$$\frac{U}{5S - (xS' + yS'')} + t.$$

On making this calculation for the various mixtures examined, this temperature was found to be 88°·2, 87°·6, 83°·5, 88°·3, 86°, 84°·9, 78°·4, 92°, and 129°·6 C. for mixtures of

10, 20, 30, 40, 50, 60, 70, 80, and 90 per cent. alcoholic strength respectively. Excluding the last temperature, as in this case a slight experimental error would greatly influence the result, the agreement between the rest is close enough to warrant the conclusion that the actual variations observed are due only to slight experimental error; and we may therefore look upon the mean of all, namely 86°·1, as being approximately the temperature at which no heat at all would be evolved, whatever be the proportion in which the alcohol and water are mixed.

The idea at once suggests itself that the whole of the phenomena under consideration are due to dissociation. For every given temperature an equilibrium may exist between the free alcohol and water on the one hand, and the compound formed between the two on the other. A rise in temperature might be accompanied by dissociation of some of the compound present, and consequent absorption of heat; a fall of temperature, on the other hand, would then be accompanied by reunion and consequent liberation of heat, whereby the apparent specific heat of the mixture would be augmented. The same idea has already been advanced by PFAUNDLER, and also by MARIGNAC, to account for the observed deviations of the specific heat of many mixtures from their calculated mean value.

A closer examination of some of the other properties of these alcoholic mixtures does not, however, tend to confirm this supposition. Thus, as is well known, considerable contraction in volume follows the mixing of alcohol and water; but this contraction is not, as might be supposed, in any degree proportional to the amount of heat evolved. Thus the maximum contraction takes place in a mixture containing about 45 per cent. of alcohol, whereas the maximum amount of heat is evolved at an alcoholic strength of about 30 per cent. The maximum elevation of the specific heat above its calculated mean value is also observed at this strength of 30 per cent.; and hence, in order to reconcile the above theory with fact, we must assume on the one hand that the amount of combination taking place at any given temperature is greatest when 30 parts of alcohol are mixed with 70 parts of water, and on the other that a given rise of temperature will produce in this mixture of alcohol and water a greater amount of decomposition or dissociation than in any other. We should thus have the maximum amount of chemical action and the feeblest union both occurring with one and the same proportion of alcohol and water.

The rate of expansion of the various mixtures seems also opposed to the supposition that dissociation is the cause of the high specific heat observed. It is to be supposed that the greater the amount of dissociation the more nearly would the specific gravity observed correspond to its calculated value. In other words, the rate of expansion of all the mixtures should be above its mean value, and this excess should stand in some relation to the observed elevation of the specific heat. The following Table will show that this is by no means the case. It gives for spirits of 30, 20, and 10 per cent. strength by weight, the specific gravities as found and as calculated for the temperatures 0°, 10°, 20°, 30°, and 70° C. The specific gravities for the temperatures 0, 10, 20, and 30 are taken from the Tables of MENDELEJEFF.

TABLE X.

Temperature, in degrees Centigrade.	Specific gravity.		Difference.
	Found.	Calculated.	
	30 per cent. spirit.		
0	96540	93268	+3272
10	95998	92907	3091
20	95403	92490	2913
30	94751	91988	2763
70	91669	89389	2280
	20 per cent. spirit.		
0	97566	95407	+2159
10	97263	95142	2121
20	96877	94805	2072
30	96413	94386	2027
70	93863	92024	1839
	10 per cent. spirit.		
0	98493	97643	+ 850
10	98409	97508	901
20	98191	97259	936
30	97892	96914	978
70	95815	94815	1000

The specific gravity of the 30 per cent. spirit thus really approaches more and more to its calculated value; in the case of the 20 per cent. spirit this approach, though still perceptible, is, however, considerably less, both absolutely and proportionally. Finally, with the 10 per cent. spirit, the phenomenon is actually reversed, the observed specific gravity gradually receding from the specific gravity as calculated; and so far from any dissociation being indicated, the opposite rather seems to take place.

It may be well here to recall to mind that 5 grms. of a 30 per cent. spirit, when heated from 0° to 70° C., require about 25 units of heat in excess of what would be necessary to raise the constituents separately through the same interval. This excess amounts to about 21 units with the 20 per cent. spirit, and to about 13 units in the case of the 10 per cent. spirit. No apparent connexion, therefore, seems to exist between the rate of expansion and the high specific heat.

Methylic Alcohol and Water.

The great volatility of methylic alcohol presents considerable difficulties to the accurate estimation of the various properties of these mixtures, more particularly as regards the specific heat and the heat evolved on mixing. In addition to this, the elevation of the specific heat of the various mixtures above the calculated value is but small, and therefore even slight errors will have a much greater influence on any calculations based on the difference between the values as found and as calculated.

10 per cent. mixture.

In the formation of 5 grms. of a 10 per cent. mixture are evolved, at a temperature of

$5^{\circ}\cdot8$ C.,	23·65	units of heat.	
19·64 C.,	20·93	"	"
Difference	2·72	"	"

30 per cent. mixture.

In the formation of 5 grms. of this mixture are evolved, at a temperature of

$6^{\circ}\cdot4$ C.,	45·75	units.
17·38 C.,	44·74	"
Difference	1·01	"

Endeavours to estimate the heat evolved at higher temperatures led to still less satisfactory results. At the end of every experiment the mixture was found to be weaker in spirit than it should have been, from the amounts of water and alcohol taken; and this loss of alcohol of course diminished the amount of heat evolved. This loss took place although the mixing was effected in a closed vessel. Nevertheless these experiments show distinctly that less heat is evolved at the higher temperature.

Calculating, as in the previous mixture, the temperature at which no heat would be evolved on mixing, the following temperatures are obtained:—152°, 175°, 173°, 154°, 162°, 160°, 147°, 175°, and 146° for strengths of 10, 20, 30, 40, 50, 60, 70, 80, and 90 per cent. respectively; the mean of these temperatures is 156° C. These temperatures differ apparently somewhat widely, and yet the maximum deviation from the mean found corresponds to a small error only in the estimation of the specific heat of the corresponding mixture. Thus the maximum differences are found at an alcoholic strength of 20 and 80 per cent. The specific heat of these two mixtures as found is 95·91 and 69·99, whereas the specific heat corresponding to the above mean temperature of 156° would be 96·42 and 69·54; the difference in either case is less than $\frac{1}{150}$ of the total value. A glance at Table II. will show that in this, as in the previous mixture, the rate of expansion seems incompatible with the supposition that the high specific heat observed is caused by dissociation. For weak and for strong mixtures the rate of expansion is below the mean, for mixtures of middle strength above the mean; in the first two cases the amount of contraction is greater, in the last case it is less, the higher the temperature. The specific heat does not, however, show any corresponding change.

*Water and Prussic Acid**.

CNH one part.
H_2O one part.

Specific heat of prussic acid . . .	·2940
„ „ „ mixture found . ·	·8317
„ „ „ „ calculated .	·6470

In the formation of 5 grms. of this mixture are absorbed, at a temperature of

0° C.,	26·61 units.
14 C.,	40·54 „
Difference	13·93 „

To heat 5 grms. of the mixture from 0° to 14° requires			58·219 units.	
„ 2·5 „ of water requires	35·00 units.			
„ 2·5 „ prussic acid requires	10·29 „			
	45·29		45·290 „	
		Difference	12·929 „	

*Ethylic Alcohol and Bisulphide of Carbon**.

CS 62·3 parts.
C_2H_6O 37·7 „

Specific heat of bisulphide	·2381
„ „ „ alcohol	·5790
„ „ „ mixture found . .	·3903
„ „ „ „ calculated .	·3666

In the formation of 5 grms. of this mixture are absorbed, at a temperature of

0° C.,	5·850 units.
21·9 C.,	10·925 „
Difference	5·075 „

To heat 5 grms. of the mixture from 0° to 21°·9 requires		42·735 units.
„ „ the constituents separately from 0° to 21°·9 „		40·142 „
	Difference	2·593 „

Solutions of Potassium Chloride.

KCl one molecule, or 12·12 per cent.
H_2O thirty molecules, or 87·88 „

Specific heat of solution, according to THOMSON, ·850.

* BUSSY and BUIGNET, Ann. Chem. Phys. [4], 5.

In the formation of 5 grms. of this solution are absorbed, at a temperature of

$8^\circ\cdot9$,	34·25	units of heat.
66·55,	21·00	„ „
Difference	13·25	„ „

To heat 5 grms. of the solution from $8^\circ\cdot9$ to $66^\circ\cdot55$ requires 24·500 units.

To heat the water contained in the 5 grms. to the same extent requires 253·30 units.

KCl one molecule, or 7·952 per cent.

H_2O fifty molecules, or 92·048 „

Specific heat of solution, according to THOMSON, ·904.

In the formation of 5 grms. of this solution are absorbed, at a temperature of

$9^\circ\cdot0$,	23·85	units of heat.
64·3,	13·95	„ „
Difference	9·90	„ „

To heat 5 grms. of the solution from 9° to $64^\circ\cdot3$ requires 249·95 units.
To heat the water alone „ „ „ 254·50 „

Solution of Sodium Chloride.

$NaCl$ one part.

H_2O 7·28 parts.

Specific heat of the solution, as calculated from THOMSON'S Tables, ·8747.

In the formation of 5 grms. of this mixture are absorbed, at a temperature of

$0^\circ\cdot2$ C.,	11·25	units of heat.
10·3 C.,	9·00	„ „
17·1 C.,	8·15	„ „
70 C.,	0·00	„ „

To heat 5 grms. of this solution from $0^\circ\cdot2$ to 70° requires 305·25 units.
To heat the water alone „ „ „ 306·85 units.

Solutions of Potassium Nitrate.

KNO_3 one molecule, or 9·09 per cent.

H_2O fifty-six molecules, or 90·91 per cent.

Specific heat of this solution, calculated from THOMSON'S Tables, ·909.

In the formation of 5 grms. of this solution are absorbed, at a temperature of

$5^\circ\cdot5$,	36·45	units.
28·8,	34·85	„
Difference	1·60	„

To heat 5 grms. of this solution from 5°·5 to 23°·8 requires 83·17 units.
To heat the water alone „ „ „ 83·17 „

KNO_3 one molecule, or 4·76 per cent.
H_2O 112·3 molecules, or 95·24 „

Specific heat of this solution, calculated from THOMSON'S Tables, ·943.

In the formation of 5 grms. of this solution are absorbed, at a temperature of

5°·7,	20·57 units.
19·7,	19·16 „
Difference	1·41 „

To heat 5 grms. of the solution from 5°·7 to 19°·7 requires 66·01 units.
To heat the water alone „ „ „ 66·66 „

The data for calculating the heat absorbed in this and in the preceding solution are taken from GRAHAM, OTTO'S 'Chemie,' vol. i. part 2, by H. KOPP.

Solution of Potassium Hydrate.

KHO one molecule, or 9·4 per cent.
H_2O thirty molecules, or 90·6 „

Specific heat of solution, according to THOMSON, ·876.

In the formation of 5 grms. of solution are evolved, at a temperature of

4°·0,	54·05 units.
31·6,	61·75 „
Difference	7·70 „

To raise 5 grms. of solution from 4° to 31°·6 requires 120·885 units.
To raise the water alone „ „ „ 125·030 „

Every one of the preceding eight mixtures conforms with proposition 2, and most of them also fairly enough with proposition 1, the only signal exception being the mixture of ethylic alcohol and bisulphide of carbon. A very close correspondence can only be expected where all the necessary data have been estimated with accuracy and at the required intervals of temperature. Some amount of error is, however, unavoidable; and that mixture which is least affected by such small errors, will serve best to bring out the real connexion existing between the various properties. Now none of the eight sets of mixtures considered equals the mixtures of ethylic alcohol and water in this respect, and we find accordingly that these most nearly conform to the law. These mixtures have therefore been chosen, not only as the best illustrations of the law, but also as a guide in tracing similar relations between the corresponding properties of other mixtures and solutions, relations which, being in those cases more liable to be masked by small experimental errors, might otherwise have been overlooked.

Apart from all speculation as to the cause of these phenomena, for which the existing data seem insufficient, a more extended study of the relations pointed out cannot fail to throw much light on the vexed question of the constitution of solutions and mixtures.

It is also evident that proposition 1 will enable us to calculate the specific heat of one constituent of a mixture if we know the specific heat of the other, the specific heat of the mixture, and the units of heat evolved or absorbed at the two different points of temperature between which these specific heats have been determined.

This calculation will serve not only as a check on the accuracy of the various experimental data involved, but may in certain cases enable us to calculate the specific heat of an element in a condition in which this could not be directly determined. If, for example, we can estimate the heat evolved or absorbed at two different temperatures during the combination of two elements, of which one is, say, in the nascent state, the specific heat of the element in that condition could be calculated.

Lastly, these considerations show how important it is to give, in all cases in which the heat of combination &c. is estimated, not only the quantities of substance employed, but also the exact temperature at which the experiment was performed. Without this the results are well nigh valueless.

Let z be the weight of a mixture, x and y the weights of its two constituents, U and U$'$ the units of heat evolved at the temperatures t and t', of which t is the lower, and S, S$'$ and S$''$ the specific heat of the mixture and of its two constituents x and y respectively; then, if S and S$'$ are known, we have

$$S''=\frac{Sz(t'-t)-U+U'-S'x(t'-t)}{y(t'-t)}.$$

If heat is absorbed in the formation of the mixtures, U and U$'$ may be taken as representing the units of heat absorbed at t and t', and the above equation becomes correct if the signs for U and U$'$ are reversed.

The specific heats of the four solids above considered, calculated with the help of this formula, are as follows:—

Potassium chloride from the weaker solution	·147
,, ,, ,, ,, stronger ,,	·135
,, ,, as estimated by KOPP directly	·173
Sodium chloride calculated	·229
,, ,, as estimated by KOPP	·214
Potassium nitrate from the weaker solution	·227
,, ,, ,, ,, stronger ,,	·192
,, ,, as estimated by KOPP	·2388
Potassium hydrate calculated	·274

Potassium hydrate has not yet been directly estimated.

Fig.

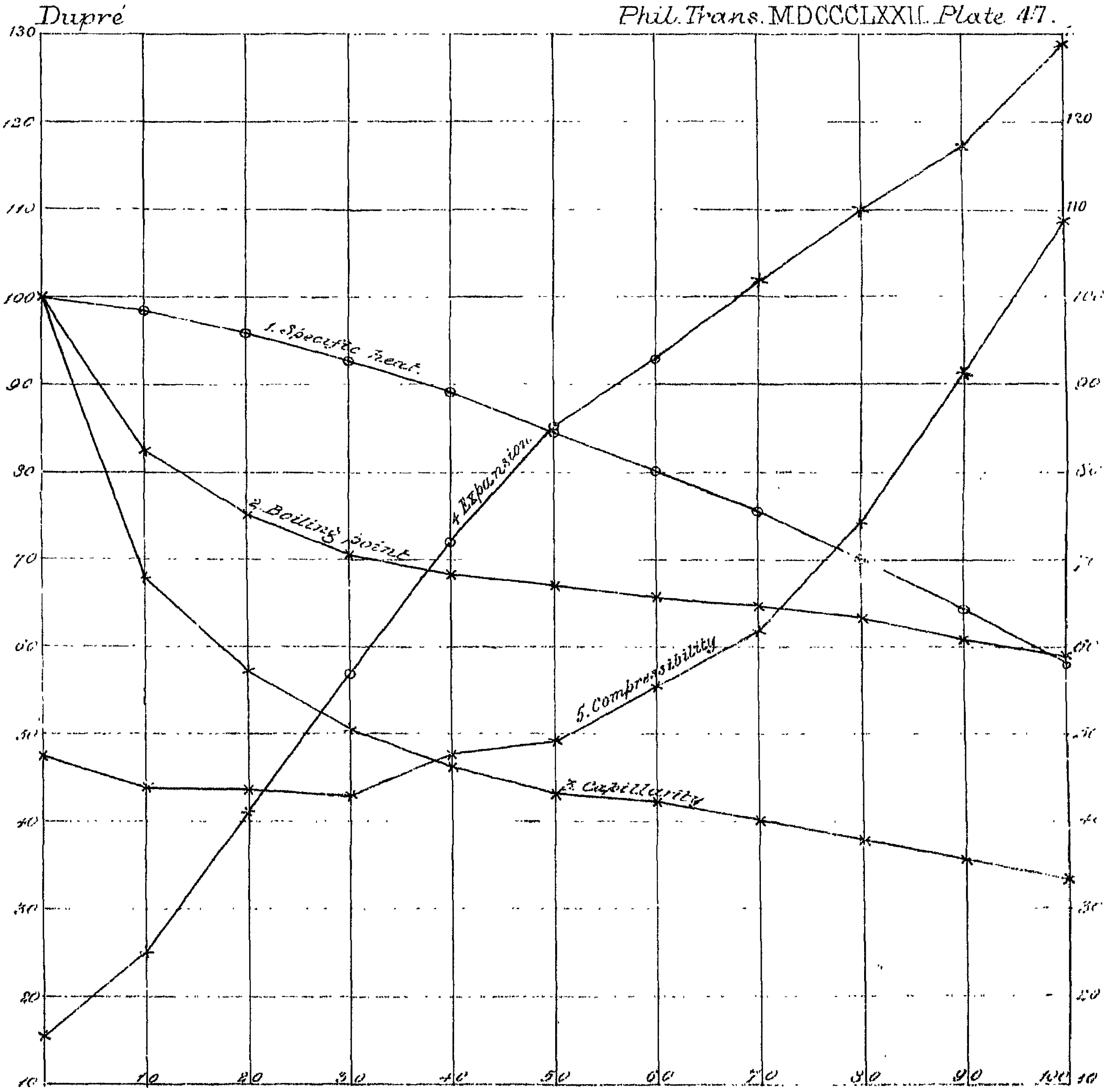
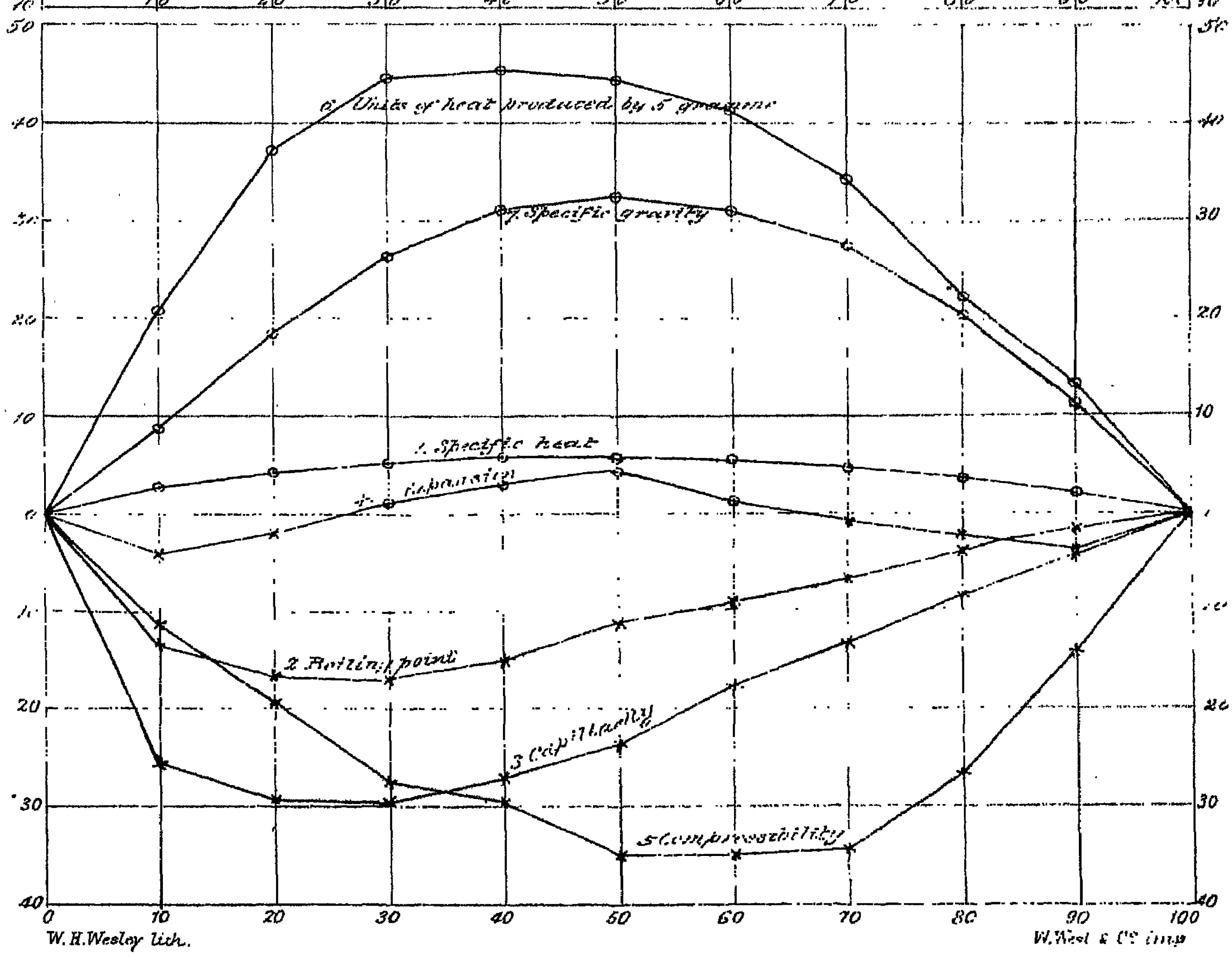


Fig. 2.



W. H. Wesley lith.

W. West & Co. imp.

Explanation of the Plate.

In the Plate the abscissæ represent the percentage by weight of alcohol.

PLATE XLVII.

Upper Half.

Curve 1. The ordinates give the specific heats, water taken as 100.
Curve 2. The ordinates give the boiling-points in degrees Centigrade, at 757·4 millims. pressure.
Curve 3. The ordinates give the capillarity in millims., water =100.
Curve 4. The ordinates give the expansion for 10,000 volumes.
Curve 5. The ordinates give the compressibility in millionths.

Under Half.

The ordinates in Curves 1 to 5 have the same significance as in the upper half, except that they give the deviation of the numbers found from the theoretical mean instead of the numbers themselves.

Curve 6 gives the heat produced by mixing, the ordinates representing units of heat.

Curve 7. The ordinates give the deviation of the specific gravity from the mean, for 1000 volumes of mixture, at a temperature of 10° Centigrade.

The zero line represents the mean value of all the properties.

The points directly ascertained by experiment are marked either by a circle or a cross.

XVI. *Contributions to Terrestrial Magnetism.*—No. XIII.

By General Sir Edward Sabine, *K.C.B.*, *V.P.R.S.*

Received June 19,—Read June 20, 1872.

In this, the XIII.th Number of the "Contributions to Terrestrial Magnetism," I have the pleasure of presenting to the Royal Society the Magnetic Survey of the North Polar Regions of the Globe, in a suitable form and arrangement to entitle it to be regarded as a companion to the Magnetic Survey of the South Polar Regions, presented to the Society in 1868; constituting, with the present contribution, a moiety of the Magnetic Survey of the Globe corresponding to the general epoch 1840 to 1845. The area comprised in the present communication is coextensive with that of the South Polar Survey, and the epochs are the same, viz. 1840 to 1845, or more simply 1842·5; the chief distinction between the two surveys being, that the South Polar Survey is the work of a single nation,—executed by the authority of its Government and at the national expense in the brief interval comprised between the years 1840 and 1845, and thus requiring no corrections to be introduced for secular change, a troublesome and not very certain operation; whilst its companion, the present communication, comprehends the cooperative labours of many European and American contributors, acting for the most part independently of each other, within the limits of about twenty years preceding, and twenty years following, the mean epoch of 1842·5: the results, therefore, when brought together, require the introduction of "corrections for secular change," where these are practicable, and where they can be made with safety.

The general form in which the observations collected in this Contribution are arranged is that of *zones*—each zone comprehending the observations of successive five degrees of latitude, in all longitudes, commencing with Greenwich as the first meridian and proceeding easterly until the circumference of the globe is completed. The zones are ; in number:—

Zone 1,	comprehending	from latitude	40° N.	to latitude	45° N.
Zone 2,	„	„	45° N.	„	50° N.
Zone 3,	„	„	50° N.	„	55° N.
Zone 4,	„	„	55° N.	„	60° N.
Zone 5,	„	„	60° N.	„	65° N.
Zone 6,	„	„	65° N.	„	70° N.
Zone 7,	„	„	70° N.	„	75° N.
Zone 8,	„	„	75° N.	„	80° N.

Zone 8 includes also the few observations in latitudes exceeding 80° N.

The values of the Declination and of the Inclination, recorded by the several observers, being in themselves *absolute* determinations, require for their correlation no other corrections than those for secular change. It is otherwise, however, in the case of the values representing the Magnetic Force, *prior* to the introduction of the practice now so generally adopted of determining and recording the values of the Magnetic Force, at the respective base stations, in *absolute measure*. Antecedently to the improvements in method and apparatus introduced by M. GAUSS, it was the general practice of magneticians to express their results in reference to the force at a Base Station represented by an arbitrary value, which in London was usually taken 1·372, or, as written by M. GAUSS, 1372. The base stations of British observers were commonly in the immediate vicinity of London, and as such may be fitly represented by the *Kew Observatory*, where the absolute magnetic force corresponding to a definite epoch, and its variation by reason of secular change, have been for some years past carefully determined. In the Philosophical Transactions for 1863, Art. XII. p. 302, and in the British Association Reports for 1861, p. 273, will be found the premises from which the following Table has been obtained, showing the (at least approximate) value of the Magnetic Force at the Kew Observatory in absolute measure in each year between 1830 and 1860 *, which values have now been substituted at the corresponding dates for the arbitrary value 1·372, the force at the other stations of the respective surveys being expressed proportionally:—

1830,	July.	10·27	1840,	July.	10·28	1850,	July.	10·29	1860,	July.	10·30
1831,	„	10·27	1841,	„	10·28	1851,	„	10·29	1861,	„	10·30
1832,	„	10·27	1842,	„	10·28	1852,	„	10·29	1862,	„	10·30
1833,	„	10·27	1843,	„	10·28	1853,	„	10·29	1863,	„	10·31
1834,	„	10·27	1844,	„	10·28	1854,	„	10·29	1864,	„	10·31
1835,	„	10·27	1845,	„	10·28	1855,	„	10·30	1865,	„	10·31
1836,	„	10·27	1846,	„	10·28	1856,	„	10·30	1866,	„	10·31
1837,	„	10·27	1847,	„	10·29	1857,	„	10·30	1867,	„	10·31
1838,	„	10·28	1848,	„	10·29	1858,	„	10·30	1868,	„	10·31
1839,	„	10·28	1849,	„	10·29	1859,	„	10·30	1869,	„	10·31

In the general Table in which the observations collected in this memoir are arranged, the primary classification is in zones depending upon latitude as already stated, the position within the zone being determined by the longitude: the name of the observer and the date of the observation are given in all cases. So far the several entries are simply statements of facts. The additional columns,—viz. those in which the endeavour has been made to assign corrections for the effects of secular change, in the brief intervals between the dates of the observation and the mean epoch (1842·5),—have been supplied (with two notable exceptions) upon the best judgment which a careful comparison of the facts so placed in juxtaposition has enabled me to make. Generally

* Since continued to 1869.

speaking, and excepting for very special reasons, the limit of about eighteen years before and after the mean epoch has not been departed from. In the large contribution made by Dr. LAMONT, extending over a considerable portion of the European continent, I have only had to approve and to adopt his own estimate of secular change, and to apply the corrections accordingly. In a yet more extensive series, the well-known observations of MM. HANSTEEN, ERMAN, and DUE, in the northern parts of Eastern Europe and of Asia, I have been aided by my early and valued friend Professor ADOLPH ERMAN, of Berlin, by whom the secular corrections of the three elements at the Land Stations of the three observers in Zones 3, 4, 5, and 6 have been supplied. I am also indebted to Professor ERMAN for the secular corrections applied to the observations of WRANGEL and ANJOU in North-eastern Asia.

For a manuscript communication of a large portion of the Magnetic Determinations on the coasts and islands of the Asiatic Polar Sea, I have been indebted to the early and valued friendship of Admiral Count LÜTKE, himself a magnetician of no ordinary note, and who now holds the distinguished position of President of the Imperial Academy of Sciences at St. Petersburg. In assigning the Secular Corrections for these, and for other determinations around and eastward of the White Sea, I have been greatly aided by the publication (in the Russian language) of Captain BELAVENETZ, of the Russian Imperial Navy, Director of the Compass Observatory at Cronstadt.

On the American continent, and until the Arctic Regions are approached, the observations themselves furnish on the whole satisfactory materials for the assignment of secular change. The Inclination, indeed, appears to have been nearly stationary in Canada and in the northern states of America for some years before and after the mean epoch of 1842·5—a conclusion which is confirmed by the records of the Toronto Observatory, and is quite in accordance with the excellent observations and discussions in the volumes of the United States Coast Survey. But in Zones 6, 7, and 8 the American portions present more than ordinary difficulties in respect to secular change,—especially in the case of the Declination, in which element a satisfactory conclusion seemed especially desirable, as likely to possess a more than ordinary theoretical value, in addition to that attaching to it for the sake of corrections to the mean epoch. The observations are tolerably numerous, both in the earlier and in the later portions of the included time; and it must also be said that the difficulty referred to is only *partially* due to the increased amount of probable error in the observations, incident to a region where the intensity of the Terrestrial Magnetic Force acting on the Declination Magnet is so greatly reduced. This latter inconvenience is one which it has in many cases been possible to counteract in some degree, by forming *groups* of results, with due regard to proximity in time and space; but the intercomparison of such groups (so far as they might admit of intercomparison), and the general and particular consideration of the data in various ways with a view to the derivation of secular change, have failed to enable me to derive conclusions in regard to the secular change which may have taken place in those localities between 1818 and 1860 which I could put forward with sufficient

confidence. The impression produced on my own mind is the probability of a *reversal* having taken place in the direction of the secular change at some time in the interval between 1818 and 1860, whereby the direction of the change which had been "increasing Easterly" or "decreasing Westerly" in the space between Melville Island and Baffin's Bay became "decreasing Easterly" or "increasing Westerly" in the same localities. The epoch of a change of this description may indeed be supposed to have synchronized approximately with the reversal in the direction of the secular change of the Declination and of the Inclination which is now generally believed to have taken place in or about the same meridians in Canada* and the United States; and it may be right to connect both with the easterly progression of the phenomena in *North-eastern Asia*, attesting the approach of the present Asiatic point of maximum Force to the American continent. These, however, are matters which may be safely left to the elucidation they may receive from future researches in the same or in approximate localities; towards which the best service which can be at present rendered is the assemblage in groups, approximate in time and locality, of the facts which we now possess. Such an assemblage will be found at the close of Zone 8.

Amongst the Magnetic Determinations *made at sea*, the fine series of Professor ADOLPH ERMAN in the corvette 'Krotkoi' (commencing at Kamtschatka in October 1829, passing round Cape Horn, and terminating at St. Petersburg in October 1830) may claim a special notice, both on account of the extent of oceanic surface which it covers, and the regard given to all the incidental circumstances which are conducive to the accuracy of conclusions obtained on board ship. The results are found in his well-known publication, the 'Reise um die Erde' (Berlin, 1841). I have found nothing either to alter or to add in the Declinations and Inclinations recorded in that volume (excepting the introduction of the secular corrections furnished by himself, of which I have already spoken); in regard, however, to the values assigned to the magnetic *Force*, I have availed myself of the observations made by Professor ERMAN, in the return voyage to Europe, at Portsmouth in August 1830, to bring the whole series of his sea observations of the Force, of which those at Portsmouth formed a part, into direct comparison with the values assigned by British observers. The Magnetic Survey of the British Islands (Phil. Trans. 1870, Art. XIV.) assigns as the value of the Total Force at the "Mother-

* There is direct evidence of a reversal in the direction of the secular change in the Declination having taken place at York Fort, from Easterly increasing to Easterly diminishing, about the date 1842, in the record of three careful observers, FRANKLIN, LEFROY, and BLAKISTON (Proceedings of the Royal Society, January 7, 1858).

The observations of FRANKLIN in September 1819 gave	6° 06′ E.
Those of LEFROY in July 1843 gave	9 25 E.
Those of BLAKISTON in August 1857 gave	7 37 E.

The reversal in the direction of the secular change of the Declination possibly took place at York Fort, as it may have done at Toronto, somewhat earlier than 1842·5; it is impossible to speak with *certainty* in regard to the precise epoch of the reversal at Toronto, because the Magnetic Observatory at that station was only established in 1840.

bank" at Portsmouth, in 1836 and 1837, 10·23 in British units, which in Professor ERMAN's Table (Reise, p. 579) has the corresponding value 1·33019 in the scale adopted by him. The ratio thus established between ERMAN's scale and the corresponding values in British units, when carried back to the value assigned in the 'Reise' to the Force at Kamtschatka (viz. 1·47370, p. 576), shows an amount of loss in the magnetism of the needle employed which may well be deemed insignificant in a voyage which lasted an entire year, and in which the magnetic instruments were in constant employment.

I have again to express how greatly these Contributions have been and are indebted to the Hydrographer of the Admiralty, Admiral RICHARDS, F.R.S., for his kind permission to have the Maps (which accompany this and former Numbers of the Contributions) prepared at the Hydrographic Office; and have again to make my special acknowledgments to the Assistant Hydrographer, Captain FREDERICK JOHN EVANS, R.N., F.R.S., for the very valuable superintendence which he has kindly given to their preparation and execution.

Those who are familiar with the records of our early British navigators, the honoured predecessors of our modern British Polar Voyagers, will scarcely need to be reminded of their *Magnetical* Observations, bearing testimony to the fact that at that early period Inclinations of a much higher value than those which are now observed in the same localities prevailed on the coast of Norway, and in the Spitzbergen and Nova-Zembla seas. The careful and apparently dependable observations of HENRY HUDSON and others in the first years of the 17th century contain the record of systematic observations exceeding 80° of Inclination (viz. from 80° to upwards of 86°) in localities where the Inclinations are now fully 10° less. It was at that period the frequent practice to observe the Inclination at sea on days suitable for the observation, and great attention appears to have been given to the subject: no doubt the instruments of those days were less precise than modern ones; but, on the other hand, the very small amount of iron then used in the construction of ships must have obviated in great measure the chief difficulty attaching to more modern magnetic determinations at sea in the higher latitudes. There is much to make it probable that the high values of the Inclination which have since prevailed on the northern coast of Asia, and are now found on the northern coast of America, were then existing on the northern coasts of Europe, and are now adducible in evidence of that progress of secular change, with which are also connected the now well-established phenomena in the northern parts of Siberia, which I have elsewhere ventured to regard as, in part at least, an effect of *cosmical* influence.

ZONE I.—LATITUDE 40° TO 45° N.

Authorities.

Lamont.......... Erdmagnetismus südwestlichen Europa's (München, 1858), and Sonnen-Finsterniss in 1860 (München, 1862).

Norwegian Officers... Hansteen, Mag. Beob. (Christiania, 1863).

Perry .... Magnetic Survey of the West of France, Philosophical Transactions, 1870; and of the East of France, Royal Society Proceedings, 1871.

Bérard	MSS. in Magnetic Office, communicated by Admiral Duperrey.
Fox	Contributions to Terrestrial Magnetism, Philosophical Transactions, 1840; and Cornwall Polytechnic Society's Reports, 1859.
Darondeau	Voyage de la Bonite, 1836 et 1837 (Paris, 1842).
Hall, Blosseville, Gauttier, Parrot, D'Urville	MSS. in Magnetic Office, communicated by Professor L. S. Kämtz.
Quetelet	Mém. de l'Acad. Roy. de Bruxelles, vol. vi.
Kämtz, L. F. von	Mem. by Rikatcheff; Repertorium für Meteor. Bd. I. Heft 2, 1870 (Petersburg).
Wild	Repertorium für Meteor. Band I. Heft 2 (Petersburg, 1870).
Bache	Magnetic Observations at Stations in Europe, Trans. Am. Phil. Soc. 1840; at Stations in America, vol. v. of the same work; Smithsonian Contr. vol. xiii.; and in other publications.
Secchi	Ast. Nach. 1871.
Kreil	Mag. und Geog. Bestimmungen im Südost Europa's &c. (Wien, 1862).
Novara (Austrian Frigate)	Reise um die Erde (Wien, 1862–5).
Russian Officers	MSS. in Magnetic Office, communicated by Professor L. S. Kämtz.
Dirkoff	MSS. in the British Hydrographic Office.
Ainsworth	London Geographical Journal, vol. viii. 1838.
Golouchef	Ann. de l'Obs. Phys. Central de Russie, 1859.
Fritsche	Repert. für Meteor. Band I. Heft 2, 1870.
Fuss, G. von	Mag. und geog. Bestimmungen in Sibirien, &c. in 1830–32, Acad. Sci. Petersb. Mem. III. 1838.
Ivatinsk	Survey of the Caspian Sea, St. Petersburg, 1870 (in Russian).
Kowanko, Schatskoff	Memoir by Fritsche in Wild's Repertorium for 1870, Band I. Heft 2.
Richards, Shadwell, Rodgers	MSS. communicated by the British Hydrographic Office.
Kellett, Collinson, Moore, Crane	(Sea Observations.) MSS. in Magnetic Office, communicated by the British Hydrographic Office.
Lütke	Mem. by Lenz, in the Acad. Sci. Mém. St. Pétersb. 1838.
Erman	Reise um die Erde, Berlin, 1831.
United States Coast Survey	Annual Reports, 1856 to 1863.
Douglas (David)	Report on the Variations of the Earth's Magnetic Force, British Association Reports, 1838.
Locke	Amer. Phil. Society, 1840, vol. ix.; U. S. Coast Survey; Contrib. to Terr. Mag., Phil. Trans. 1846; and Smithsonian Contributions, vol. iii.
Graham	Amer. Phil. Soc. Trans. New Series, vol. ix. Art. XII.
Loomis	Amer. Phil. Soc. Trans. 1839, 1842, and 1843; and Contrib. to Terr. Mag., Phil. Trans. 1846.
Lefroy, Nicollet, Younghusband, Renwick	Contrib. to Terr. Mag. No. VII. Phil. Trans. 1846; and in U. S. Coast Survey.
Various observers in the U. S.	U. S. Coast Survey, years 1856 to 1863.
Various observers at sea in the Atlantic Ocean	Contrib. to Terr. Mag. No. IX. Phil. Trans. 1849, Art. XII.; and MSS. communicated by the Hydrographic Office.

ZONE I.—Lat. 40° to 45° N.

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.		Inclination. Observed.	Inclination. Correction to Epoch 1842·5.	Inclination. Corrected.		Force in British units.		Observers.
	° ′	° ′		° ′	° ′	°		° ′	′	°				
Agen	44 13	0 36	1858·0	19 15 w.	1 58 w.	21·2 w.		63 22	+42	64·1		9·91		Lamont.
Salon	41 07	1 13	1833·5	......	......	......	°	62 26	−24	62·0	°	......		Norwegian Officers.
Toulouse	43 36	1 26	1858·0	18 45 w.	1 58 w.	20·7 w.	20·7 w.	62 46	+42	63·5	63·4	9·89	9·84	Lamont.
			1869·0	17 12 w.	3 21 w.	20·6 w.		62 01	+72	63·2		9·78		Perry.
Martorell	41 31	1 45	1858·0	18 12 w.	1 58 w.	20·2 w.		60 52	+42	61·6		9·72		Lamont.
Barcelona	41 23	2 11	1858·0	18 05 w.	1 58 w.	20·1 w.	20·1 w.	60 42	+42	61·4	61·4	9·88	9·80	Lamont.
			1860·5	17 53 w.	2 14 w.	20·1 w.		60 31	+49	61·3		9·71		Lamont.
Carcassonne	43 13	2 21	1858·0	18 17 w.	1 58 w.	20·3 w.		62 12	+42	62·9		9·83		Lamont.
At sea	40 03	2 22	1842·5	18 30 w.	......	18·5 w.		......	......	......		......		Bérard.
Arenys de Mar	41 35	2 23	1858·0	17 52 w.	1 58 w.	19·8 w.		60 48	+42	61·5		9·71		Lamont.
At sea	40 35	2 29	1842·5	20 00 w.	......	20·0 w.		......	......	......		......		Bérard.
[illegible]	[illegible] 11	2 38	1842·5	19 30 w.	......	19·5 w.		......	......	......		......		Bérard.
Gerona	41 52	2 48	1858·0	17 54 w.	1 58 w.	19·9 w.		......	......	......		......		Lamont.
Perpignan	42 42	2 55	1858·0	17 59 w.	1 58 w.	20·0 w.	20·0 w.	61 48	+42	62·5	62·4	9·78		Lamont.
			1860·5	17 48 w.	2 14 w.	20·0 w.		61 30	+49	62·3				Lamont.
Figueras	42 16	2 57	1860·5	17 37 w.	2 14 w.	19·9 w.		60 59	+49	61·8		9·72		Lamont.
Narbonne	43 11	3 00	1858·0	18 01 w.	1 58 w.	20·0 w.		62 06	+42	62·8		9·82		Lamont.
Cette	43 24	3 12	1858·0	17 08 w.	1 58 w.	19·1 w.		......	......	......		......		Lamont.
At sea	41 26	3 51	1842·5	19 30 w.	......	19·5 w.		......	......	......		......		Bérard.
Montpellier	43 36	3 53	1858·0	......		......		62 15	+42	63·0	62·9	9·83	9·80	Lamont.
			1869·0	16 32 w.	3 21 w.	19·9 w.		61 37	+72	62·8		9·75		Perry.
At sea	41 32	4 17	1842·5	19 00 w.	......	19·0 w.		......	......	......		......		Bérard.
Nismes	43 51	4 21	1838·5	......	......	......		63 26	−11	63·3		......		Fox.
Montelimar	44 34	4 45	1858·0	17 36 w.	1 58 w.	19·6 w.		62 53	+42	63·6		9·87		Lamont.
At sea	42 04	4 47	1842·5	18 30 w.	......	18·5 w.		......	......	......		......		Bérard.
Avignon	43 57	4 48	1869·0	16 03 w.	3 21 w.	19·4 w.		61 50	+72	63·0		9·79		Perry.
Orange	44 08	4 48	1838·5	......	......	......		63 38	−11	63·5	63·4	......		Fox.
			1858·0	17 28 w.	1 58 w.	19·4 w.		62 37	+42	63·3		9·87		Lamont.
Valence	44 56	4 53	1838·5	......	......	......		64 11	−11	64·0	63·9	......		Fox.
			1860·5	17 20 w.	2 17 w.	19·6 w.		62 57	+49	63·8		9·85		Lamont.
Marseilles	43 18	5 22	1854·0	17 35 w.	1 24 w.	19·0 w.	19·0 w.	61 58	+31	62·5	62·5	......	9·67	De La Rive.
			1858·0	17 04 w.	1 58 w.	19·0 w.		61 41	+42	62·3		9·73		Lamont.
			1859·5	......	......	......		61 47	+45	62·5		......		Fox.
			1869·0	15 41 w.	3 21 w.	19·0 w.		60 35	+72	61·8		9·61		Perry.
Toulon	43 07	5 55	1826·5	19 40 w.	2 02 E.	17·6 w.	18·0 w.	63 47	−43	63·1	62·6	......		D'Urville.
			1826·5	19 19 w.	2 02 E.	17·3 w.		62 58	−43	62·3		......		Blosseville.
			1836·5	19 16 w.	0 46 E.	18·5 w.		62 52	−16	62·6		......		Darondeau.
			1843·5	......	......	......		62 27	0	62·5		9·84	9·81	Norwegian Officers.
			1860·5	16 31 w.	2 14 w.	18·7 w.		61 31	+49	62·3		9·78		Lamont.
Nice	43 42	7 17	1859·5	......	......	......		61 40	+46	62·4		......		Fox.
Monaco	43 43	7 25	1869·5	14 31 w.	3 21 w.	17·9 w.		61 22	+72	62·6		9·72		Perry.
Mentone	43 43	7 36	1859·5	......	......	......		61 44	+46	62·5		......		Fox.
Oneglia	43 55	8 00	1859·5	......	......	......		61 35	+46	62·4		......		Fox.
Sagona	42 06	8 41	1824·5	19 19 w.	2 17 E.	17·0 w.		......	......	......		......		Hall.
Ajaccio	41 55	8 44	1824·5	18 45 w.	2 17 E.	16·5 w.		......	......	......		......		Hall.
Calvi	42 34	8 45	1824·5	18 26 w.	2 17 E.	16·2 w.		......	......	......		......		Hall.
Genoa	44 24	8 54	1839·5	......	......	......		62 53	−08	62·8		9·82		Quetelet.
La Ruta	44 18	9 10	1859·5	......	......	......		61 38	+46	62·4		9·85		Fox.
Spezzia	44 04	9 51	1867·5	......	......	......		61 09	+67	62·3		......		Kämtz, L. F.
Boliaccio	44 10	10 00	1859·5	......	......	......		61 38	+46	62·4		9·84		Fox.
Leghorn	43 33	10 18	1828·0	19 20 w.	1 46 E.	17·6 w.		......	......	......		......		Becquerel.
			1867·5	......	......	......		60 34	+67	61·7		......		Kämtz, L. F.
Porto Ferrajo	42 49	10 20	1828·0	16 29 w.	1 46 E.	14·7 w.		......	......	......		......		Becquerel.
Pisa	43 43	10 24	1839·5	......	......	......		62 19	−08	62·0		9·80		Quetelet.
			1859·5	......	......	......		60 54	+46			......		Fox.
Modena	44 39	10 56	1867·5	......	......	......		61 27	+67	62·6		......		Kämtz, L. F.
Florence	43 46	11 14	1838·5	......	......	......		62 05	−11	61·9	62·0	......		Bache.
			1839·5	......	......	......		62 21	−08	62·2		......		Amici.
			1839·5	......	......	......		62 12	−08	62·1		......		Quetelet.
			1859·5	......	......	......		61 00	+46	61·8		......		Fox.
Bologna	44 50	11 21	1867·5	......	......	......		61 19	+67	62·4		......		Kämtz, L. F.

ZONE I.—Lat. 40° to 45° N. (continued).

[illegible]	[illegible]	[illegible]	1859·5					[illegible]	[illegible]	[illegible]				[illegible]
[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
			[illegible]					[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
			[illegible]					[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
			[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
			[illegible]					[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
Terni	42 35	12 30	1859·5	......	......	......		59 52	+46	60·6		9·68		Fox.
Spoleto	42 45	12 36	1859·5	......	......	......		59 48	+46	60·6		9·71		Fox.
Terracina	41 18	13 15	1859·5	......	......	......		58 37	+46	59·4		......		Fox.
Ancona	43 38	13 30	1850·0	14 16 w.	0 53 w.	15·2 w.		61 06	+20	61·4		......		Kreil.
Pola	44 53	13 50	1850·0	14 16 w.	0 53 w.	15·2 w.		62 14	+20	62·6		......		Kreil.
Naples	40 15	14 15	1838·5	......	......	......		59 05	−11	58·9	58·9	9·53	9·55	Bache.
			1839·5	......	......	......		58 59	−08	58·9		9·55		Quetelet.
			1843·5	......	......	......		58 42	+03	58·8		9·55		Norwegian Officers.
			1859·5	......	......	......		58 09	+46	58·9		9·56		Fox.
Sorrento	40 35	14 25	1859·5	......	......	......		58 02	+46	58·8		9·52		Fox.
Lussin Piccolo	44 32	14 28	1850·0	14 13 w.	0 53 w.	15·1 w.		61 53	+20	62·2		9·76		Kreil.
Cava	40 40	14 43	1859·5	......	......	......		57 59	+46	58·8		9·48		Fox.
Zara	44 07	15 15	1850·0	13 53 w.	0 53 w.	14·8 w.		61 53	+19	62·2		9·72		Kreil.
Ottocaz	44 51	15 24	1850·0	13 59 w.	0 53 w.	14·9 w.		61 57	+19	62·3		9·79		Kreil.
Mali Hallan	44 22	15 43	1850·0	......	......	......		61 33	+19	61·9		9·79		Kreil.
Sebenico	43 44	15 59	1850·0	13 37 w.	0 53 w.	14·5 w.		60 58	+18	61·3		9·74		Kreil.
Lissa	43 05	16 11	1850·0	13 08 w.	0 53 w.	14·0 w.		59 44	+18	60·1		9·65		Kreil.
Spalato	43 31	16 27	1850·0	13 28 w.	0 53 w.	14·4 w.		60 43	+18	61·0		9·72		Kreil.
Lesina	43 11	16 27	1850·0	13 18 w.	0 53 w.	14·2 w.		......	......	......		......		Kreil.
Molfetta	41 13	16 41	1850·0	12 51 w.	0 53 w.	13·7 w.		58 05	+18	58·4		9·51		Kreil.
Lagosta	42 47	16 52	1850·0	12 58 w.	0 53 w.	13·9 w.		......	......	......		......		Kreil.
Curzola	42 59	17 08	1850·0	12 58 w.	0 53 w.	13·9 w.		59 55	+17	60·2		9·66		Kreil.
Brindisi	40 39	18 00	1850·0	12 16 w.	0 53 w.	13·2 w.	13·2 w.	57 21	+17	57·6		9·55		Kreil.
			1870·0	10 06 w.	3 12 w.	13·3 w.		......	......	......		......		Ast. Nach. 1871.
Gravosa	42 40	18 05	1850·0	12 26 w.	0 53 w.	13·3 w.		59 21	+17	59·6		9·60		Kreil.
Ragusa	42 38	18 07	1850·0	12 18 w.	0 53 w.	13·2 w.		59 30	+15	59·8		9·57		Kreil.
At sea	42 14	18 24	1859·5	10 14 w.	1 59 w.	12·2 w.		......	......	......		......		Novara.
Megline	42 27	18 31	1850·0	12 31 w.	0 53 w.	13·4 w.		59 04	+15	59·3		9·59		Kreil.
Cattaro	42 25	18 46	1850·0	12 03 w.	0 53 w.	12·9 w.		59 24	+15	59·7		9·71		Kreil.
Cettigne	42 24	18 59	1850·0	......	......	......		59 06	+15	59·4		9·63		Kreil.
Antivari	42 06	19 09	1850·0	12 13 w.	0 53 w.	13·1 w.		58 36	+15	58·9		9·54		Kreil.
Durazzo	41 19	19 28	1850·0	11 56 w.	0 53 w.	12·8 w.		58 02	+15	58·3		9·55		Kreil.
Valona	40 29	19 30	1850·0	11 51 w.	0 53 w.	12·7 w.		57 05	+15	57·3		9·49		Kreil.
Posehega	43 52	19 59	1850·0	11 54 w.	0 53 w.	12·8 w.		60 36	+15	60·9		9·81		Kreil.
Semlin	44 50	20 24	1850·0	11 27 w.	0 53 w.	12·3 w.		61 13	+15	61·5		9·73		Kreil.
Belgrade	44 48	20 25	1850·0	11 18 w.	0 53 w.	12·2 w.		61 16	+15	61·5		9·88		Kreil.
Weisskirchen	44 54	21 25	1850·0	11 02 w.	0 53 w.	11·9 w.		61 08	+15	61·4		9·77		Kreil.
Alexinatz	43 34	21 36	1850·0	11 32 w.	0 53 w.	12·4 w.		60 08	+15	60·4		9·79		Kreil.
Orsowa	44 42	22 24	1850·0	10 35 w.	0 53 w.	11·5 w.		60 47	+15	61·0		9·75		Kreil.
Mehadia	44 53	22 25	1850·0	10 37 w.	0 53 w.	11·5 w.		60 40	+15	60·9		9·67		Kreil.
Tschernetz	44 38	22 42	1831·5	14 51 w.	1 17 E.	13·6 w.		......	......	......		......		Russian Officers.
Kalafat	44 00	22 56	1831·5	11 43 w.	1 17 E.	10·4 w.	10·8 w.	......	......	......		......		Russian Officers.
			1850·0	10 19 w.	0 53 w.	11·2 w.		60 22	+15	60·6		9·81		Kreil.
Kraiowa	44 19	23 47	1831·5	12 48 w.	1 17 E.	11·5 w.		......	......	......		......		Russian Officers.
Aidos	42 42	24 48	1829·5	11 32 w.	1 31 E.	10·0 w.		......	......	......		......		Russian Officers.
Statina	44 26	24 50	1831·5	13 23 w.	1 17 E.	12·1 w.		......	......	......		......		Russian Officers.
Piteschti	44 51	24 51	1831·5	12 47 w.	1 17 E.	11·5 w.		......	......	......		......		Russian Officers.
Mogurini	43 44	24 52	1831·5	11 02 w.	1 17 E.	9·8 w.		......	......	......		......		Russian Officers.
Tirgowist	44 56	25 27	1831·5	12 48 w.	1 17 E.	11·5 w.		......	......	......		......		Russian Officers.
Ploeshti	44 56	26 01	1828·5	11 49 w.	1 38 E.	10·2 w.		......	......	......		......		Russian Officers.
Bucharest	44 26	26 05	1829·5	9 14 w.	1 31 E.	7·7 w.	8·8 w.	......	......	......		......		Russian Officers.
			1850·0	9 03 w.	0 53 w.	9·9 w.		60 14	+15	60·5		9·81		Kreil.
Shursha	43 54	26 07	1829·5	9 07 w.	1 31 E.	8·6 w.		......	......	......		......		Russian Officers.
Simnitza	43 39	26 20	1831·5	10 15 w.	1 17 E.	9·0 w.		......	......	......		......		Russian Officers.
Demotika	41 21	26 30	1829·5	11 41 w.	1 31 E.	10·2 w.		......	......	......		......		Russian Officers.

ZONE I.—Lat. 40° to 45° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.	Inclination. Observed.	Inclination. Correction to Epoch 1842·5.	Inclination. Corrected.	Force in British units.	Observers.
	° ′	° ′		° ′	° ′	°	° ′	′	°		
Adrianople	41 41	26 35	1829·5	11 35 w.	1 31 E.	10·1 w.	......	......	......	......	Russian Officers.
[illegible]	41 04	26 35	1829·5	11 36 w.	1 31 E.	10·1 w.	......	......	......	......	Russian Officers.
[illegible]	[illegible] 39	27 01	1829·5	11 20 w.	1 31 E.	9·8 w.	......	......	......	......	Russian Officers.
[illegible]	[illegible] 21	27 13	1830·5	11 06 w.	1 24 E.	9·7 w.	......	......	......	......	Russian Officers.
[illegible]	[illegible] 11	27 19	1829·5	11 14 w.	1 31 E.	9·7 w.	......	......	......	......	Russian Officers.
Prawodi	43 11	27 28	1830·5	14 41 w.	1 24 E.	13·3 w.	......	......	......	......	Russian Officers.
Burgas	42 30	27 31	1829·5	11 25 w.	1 31 E.	9·9 w.	......	......	......	......	Russian Officers.
			1850·0	8 01 w.	0 53 w.	8·9 w. } 9·1 w.	57 26	+12	57 6 } 57·4	9·89	Kreil.
			1859·5	6 36 w.	1 59 w.	8·6 w.	56 40	+28	57·1	......	Dirkoff.
Anchiola	42 33	27 42	1829·5	11 19 w.	1 31 E.	9·8 w.	......	......	......	......	Russian Officers.
Sisopol	42 25	27 45	1859·5	6 28 w.	1 59 w.	8·5 w.	......	......	......	......	Dirkoff.
Miserwi	42 40	27 47	1829·5	10 48 w.	1 31 E.	9·3 w.	......	......	......	......	Russian Officers.
Basardshik	43 34	27 54	1830·5	10 41 w.	1 24 E.	9·3 w.	......	......	......	......	Russian Officers.
Hirsowa	44 41	27 54	1828·5	11 49 w.	1 38 E.	10 2 w.	......	......	......	......	Russian Officers.
Simieni-dindel	44 22	27 56	1828·5	11 40 w.	1 38 E.	10·0 w.	......	......	......	......	Russian Officers.
Varna	43 12	27 57	1829·5	9 50 w.	1 31 E.	8·3 w. } 8·7 w.	......	......	......	......	Russian Officers.
			1859·5	7 00 w.	1 59 w.	9·0 w.	......	......	......	......	Dirkoff.
Inada	41 55	28 00	1859·5	6 24 w.	1 59 w.	8·4 w.	......	......	......	......	Dirkoff.
Balchik	43 25	28 12	1859·5	6 43 w.	1 59 w.	8·7 w.	......	......	......	......	Dirkoff.
Kavarna	43 50	28 22	1830·5	10 12 w.	1 24 E.	8·8 w.	......	......	......	......	Russian Officers.
Cape Kalakri	43 23	28 29	1850·5	7 47 w.	0 53 w.	8·7 w.	......	......	......	......	Kreil.
Mangalia	43 48	28 37	1830·5	12 13 w.	1 24 E.	10·8 w.	......	......	......	......	Russian Officers.
Kustendje	44 10	28 42	1829·5	11 33 w.	1 31 E.	10·0 w. } 9·3 w.	......	......	......	......	Russian Officers.
			1859·5	6 44 w.	1 59 w.	8·7 w.	58 49	+17	59·1	......	Dirkoff.
Constantinople	41 00	28 55	1838·0	......	......	......	56 34	− 4	56·5	......	Ainsworth.
Ortakoi ...	41 04	29 01	1850·0	7 39 w.	0 53 w.	8·5 w.	56 18	+ 7	56·4	9·55	Kreil.
Bairik Déré	41 10	29 03	1859·5	......	......	......	56 05	+17	56·4	......	Dirkoff.
Bojuk Liman	41 11	29 06	1850·0	7 34 w.	0 53 w.	8·5 w.	56 11	+ 7	56·3	9·60	Kreil.
Penderekli	41 17	31 26	1859·5	6 21 w.	1 59 w.	8·3 w.	56 02	+15	56·3	......	Dirkoff.
Amastra	41 45	32 25	1859·5	5 39 w.	1 59 w.	7·6 w.	56 10	+15	56·4	......	Dirkoff.
Cape Chersonese	44 34	33 21	1850·0	6 13 w.	0 53 w.	7·1 w.	59 48	+ 6	59·9	9·79	Kreil.
Sevastopol	44 37	33 31	1859·5	4 31 w.	1 59 w.	6·5 w.	59 12	+15	59·5	......	Dirkoff.
Niopoli	42 00	33 45	1859·5	4 40 w.	1 59 w.	6·7 w.	56 29	+15	56·7	......	Dirkoff.
Yalta	44 30	34 12	1859·5	4 10 w.	1 59 w.	6·2 w.	58 59	+15	59·2	......	Dirkoff.
Agios Antonios	41 55	34 23	1859·5	4 02 w.	1 59 w.	6·0 w.	......	......	......	......	Dirkoff.
Cape Indje	42 08	34 50	1850·0	......	......	......	57 49	+ 4	57·9 } 57·0	......	Kreil.
			1859·0	3 07 w.	1 59 w.	5·1 w.	55 58	+ 9	58·1	......	Dirkoff.
Ak Liman	42 05	35 04	1859·5	4 23 w.	1 59 w.	6·4 w.	......	......	......	......	Dirkoff.
Sinope	42 00	35 10	1824·5	8 50 w.	2 06 E.	6·7	......	......	......	......	Gauttier.
			1850·0	5 43 w.	0 53 w.	6·6 } 6·9 w.	57 42	+ 3	57·8	9·72	Kreil.
			1859·5	5 30 w.	1 59 w.	7·5	......	......	......	......	Dirkoff.
Kerge	41 40	35 14	1859·5	3 42 w.	1 59 w.	5·7 w.	......	......	......	......	Dirkoff.
Samsun	41 17	36 21	1859·5	3 09 w.	1 59 w.	5·1 w.	55 41	+ 6	55·8	......	Dirkoff.
Anapa	44 53	37 18	1859·5	2 39 w.	1 59 w.	4·6 w.	59 22	+ 6	59·5	......	Dirkoff.
Unia	41 08	37 18	1859·5	3 03 w.	1 59 w.	5·0 w.	......	......	......	......	Dirkoff.
Novorosisk	44 43	37 47	1859·5	2 37 w.	1 59 w.	4·6 w.	59 00	+ 6	59·1	......	Dirkoff.
Kerasunda	40 55	38 24	1859·5	2 42 w.	1 59 w.	4·7 w.	......	......	......	......	Dirkoff.
Trebizonde	41 00	39 46	1824·5	7 30 w.	1 48 E.	5·7	......	......	......	......	Gauttier.
			1850·0	3 05 w.	0 45 w.	5·8 } 4·5 w.	56 10	+ 3	56·2 } 55·9	9·78	Kreil.
			1859·5	2 21 w.	1 42 w.	4·1	55 30	+ 6	55·6	......	Dirkoff.
Pitsunda	43 08	40 17	1859·5	1 53 w.	1 42 w.	3·6 w.	57 21	+ 5	57·4	......	Dirkoff.
Riso	41 04	40 35	1859·5	2 33 w.	1 42 w.	4·3 w.	......	......	......	......	Dirkoff.
Soukhem Kaleh	43 00	41 00	1859·5	1 48 w.	1 42 w.	3·5 w.	57 22	+ 4	57·4	......	Dirkoff.
Redout Kaleh	42 15	41 35	1859·5	1 43 w.	1 42 w.	3·4 w.	......	......	......	......	Dirkoff.
Batum	41 39	41 37	1859·5	2 03 w.	1 42 w.	4·8 w.	......	......	......	......	Dirkoff.
Fort St. Nicholas	41 54	41 46	1859·5	1 52 w.	1 42 w.	3·6 w.	56 14	+ 4	56·3	......	Dirkoff.
Platigorsk	44 03	43 00	1869·5	0 01 w.	2 28 w.	2·5 w.	58 01	+ 4	58·1	10·11	Wild.
Tiflis	41 43	44 50	1833·5	3 47 w.	0 50 E.	2·9 w.	55 34	0	55·6	....	Parrot.
			1843·5	1 52 w.	0 05 w.	2·0 w. } 2·4 w.	......	......	...... } 55·7	...... } 9·94	Observatory.
			1845·5	......	......	......	56 02	0	56·0	......	Observatory.
			1869·5	0 02 E.	2 28 w.	2·4 w.	55 29	0	55·5	9·94	Wild.
Petrousk	43 00	47 39	1862·5	1 00 E.	1 40 w.	0·7 w.	56 49	−5	56·7	10·06	Ivatinsk.

ZONE I.—Lat. 40° to 45° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.		Inclination. Observed.	Inclination. Correction to Epoch 1842·5.	Inclination. Corrected.		Force in British units.		Observers.
	° ′	° ′		° ′	° ′	°		° ′	′	°				
Tchetchen Island	43 59	47 47	1862·5	1 21 E.	1 10 W.	0·2 E.		58 06	− 5	58·0		10·15		Ivatinsk.
Derbend	42 04	48 22	1862·5	1 07 E.	1 10 W.	0·1 W.		56 02	− 5	56·0		10·03		Ivatinsk.
Bulla Island	40 00	49 46	1862·5	0 51 E.	1 10 W.	0·8 W.		53 31	− 5	53·4		9·78		Ivatinsk.
Baku	40 22	49 58	1862·5	1 05 E.	1 10 W.	0·1 W.		54 03	− 5	54·0		9·87		Ivatinsk.
Kulali Island	44 53	50 07	1862·5	2 21 E.	1 10 W.	0·7 E.		58 58	− 5	58·9		10·27		Ivatinsk,
Cape Karagan	44 35	50 23	1862·5	2 21 E.	1 40 W.	0·7 E.		58 37	− 5	58·5		10·24		Ivatinsk.
[illegible]	41 37	50 27	1862·5	2 21 E.	1 10 W.	0·7 E.		58 38	− 5	58·6		10·25		Ivatinsk.
Jiloi Island	40 20	50 19	1862·5	1 23 E.	1 10 W.	0·3 E.		53 57	− 5	53·9		9·88		Ivatinsk.
Alexander Bay	43 38	51 15	1862·5	2 05 E.	1 10 W.	0·4 E.		57 03	− 5	57·0		10·18		Ivatinsk,
Kinderlinsk	42 41	52 42	1862·5	2 21 E.	1 10 W.	0·7 E.		56 17	− 5	56·7		10·16		Ivatinsk.
Kara-bugazsk	41 02	53 01	1862·5	1 43 E.	1 10 W.	0·4 E.		55 07	− 5	55·0		9·90		Ivatinsk.
Krasnovodsk	40 00	53 07	1862·5	1 10 E.	1 10 W.	0·0		54 07	− 5	54 0		10·04		Ivatinsk.
Wernoje	43 16	77 00	1859·5	....	......	......		58 42	0	58·7		......		Golouchef.
Zain Ussu	44 47	103 54	1831·5	0 09 E.				60 50	+33	61·4	62·1	......		Fuss.
			1868·0	0 26 E.	......	0·3 E.		63 07	−76	62·8		12·30		Fritsche.
Seuchi	44 15	110 25	1831·5	0 30 W.	.....	0·5 W.		60 43	+33	61·3		11·68		Fuss.
Kutull	43 58	110 37	1831·5	......	......	......		60 13	+33	60·8		11·60		Fuss.
Zsamein Chuduck	43 37	110 50	1831·5	......	......	......		59 23	+33	59·9		11·51		Fuss.
Schara Muren	42 24	111 13	1832·0	0 05 W.	0 10 W.	0·3 W.	0·3 W.	58 07	+32	58·7	58·8	......		Fuss.
			1868·0	0 43 W.	0 26 E.	0·3 W.		60 07	−76	58·9		11·76		Fritsche.
Gaschun	44 23	111 18	1831·5	......	......	......		60 17	+33	60·8		11·57		Fuss.
Chamarin Scharik	44 50	112 05	1831·5	......	......	......		61 03	+33	61 6		12·05		Fuss.
Mingan	43 03	112 29	1831·5	......	......	......		58 49	+33	59·4		11 50		Fuss.
Batchai	44 21	112 54	1831·5	0 59 W.	0 11 W.	1·2 W.		60 18	+33	60·9		11·85		Fuss.
Sudshi	42 28	113 50	1831·5	......	......	......		58 05	+33	58·6		11·41		Fuss.
Kulchuduck	43 29	113 51	1831·5	......	......	......		59 11	+33	59·8		11·74		Fuss.
Scharabudargana	43 11	114 05	1831·5	0 16 W.	0 11 W.	1·0 W.		59 03	+33	59·6		11·73		Fuss.
Zackildack	42 48	114 16	1831·5	......	......	......		58 25	+33	59·0		11·55		Fuss.
Zsamein-ussu	41 46	114 37	1831·5	......	......	......		57 24	+33	58·0		11·49		Fuss.
Zagan Balgassu	41 18	114 43	1831·5	......	......	......		56 41	+33	57·2		11·18		Fuss.
Chalgan	40 49	115 57	1831·5	1 13 W.	0 11 W.	1·4 W.	1·5 W.	56 17	+33	56·8	56·7	11·14	11·3	Fuss.
			1868·0	1 59 W.	0 26 E.	1·6 W.		57 53	−76	56·6		11·68		Fritsche.
Wladimir Bay	43 55	135 28	1859·0	......	......	......		58 38	?	?		......		Shadwell.
At sea	40 56	139 40	1855·5	3 27 W.	......	3·5 W.		......	......	......		......		Richards.
Island of Yesso	41 47	140 40	1855·5	3 38 W.	......	3·6 W.		......	......	......		......		Richards.
Kamedia	41 49	140 48	1854·5	4 30 W.	......	4·5 W.		......	......	......		......		Richards.
Hakodadi	41 46	140 59	1855·5	4 12 W.	......	4·2 W.		......	......	......		......		Rodgers.
At sea	40 13	156 40	1851·5	......	......	......		51 55	......	51·9		......		Collinson.
At sea	42 08	156 41	1828·5	2 26 E.	?	2·4 E.		......	......	......		......		Lütke.
At sea	41 45	162 15	1849·5	5 15 E.	......	5·3 E.		......	......	......		......		Kellett.
At sea	44 53	162 40	1850·5	......	......	......		56 14	......	56·2		......		Collinson.
At sea	42 10	168 58	1850·5	......	......	......		55 47	......	55·8		......		Collinson.
At sea	41 31	169 03	1850·5	11 10 E.	......	11·2 E.		......	......	......		......		Collinson.
At sea	43 29	173 06	1848·5	......	......	......		58 26	......	58·1		......		Moore.
At sea	41 52	174 36	1848·5	......	......	......		56 00	......	56·0		......		Moore.
At sea	41 17	178 00	1848·5	......	......	......		57 33	......	57·5		......		Moore.
At sea	40 05	182 44	1848·5	......	......	......		57 14	......	57·2		......		Moore.
At sea	44 43	190 53	1852·5	16 02 E.	......	16·0 E.		......	......	......		......		Crane.
At sea	42 11	193 46	1852·5	15 42 E.	......	15·7 E.		......	......	......		......		Crane.
At sea	44 31	197 24	1849·5	18 54 E.	......	18·9 E.		......	......	......		......		Kellett.
At sea	43 20	200 32	1849·5	18 06 E.	......	18·1 E.		......	......	......		......		Kellett.
At sea	42 39	204 30	1849·5	18 08 E.	......	18·1 E.		......	......	......		......		Kellett.
At sea	41 59	207 07	1849·5	19 08 E.	......	19·1 E.		......	......	......		......		Kellett.
At sea	40 29	212 54	1849·5	17 31 E.	......	17·5 E.		......	......	......		......		Kellett.
At sea	40 28	213 35	1827·5	17 11 E.	......	17·2 E.		62 44	......	62·7		11·32		Lütke.
At sea	41 43	214 41	1851·5	14 07 E.	......	14·1 E.		......	......	......		......		Collinson.
At sea	44 54	214 50	1827·5	......	......	......		65 40	......	65·7		12·23		Lütke.
At sea	40 02	214 51	1849·5	16 52 E.	......	16·9 E.		......	......	......		......		Kellett.
At sea	43 17	230 04	1829·5	......	......	......		66 40	......	66·7		12·07		Erman.
At sea	40 19	233 08	1829·5	17 06 E.	......	17·1 E.		......	......	......		......		Erman.
At sea	40 03	233 20	1829·5	16 12 E.	......	16·2 E.		63 57	......	64·0		11·80		Erman.
Port Orford	42 44	235 31	1852·0	18 29 E.	......	18·5 E.		......	......	......		......		U. S. Coast Survey.
Crescent City Light	41 45	235 49	1851·5	17 52 E.	......	17·9 E.		......	......	......		......		U. S. Coast Survey.
Bucksport	40 47	235 49	1853·5	17 06 E.	......	17·1 E.		......	......	......		......		U. S. Coast Survey.
Shelter Cove	40 01	235 57	1857·5	17 02 E.	......	17·0 E.		......	......	......		......		U. S. Coast Survey.

ZONE I.—Lat. 40° to 45° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.	Inclination. Observed.	Inclination. Correction to Epoch 1842·5.	Inclination. Corrected.	Force in British units.	Observers.
	° ′	° ′		° ′	° ′	°	° ′	′	°		
River Sandiam	44 35	237 33	1830·0	......	......	......	68 28	−02	68·4	12·51	Douglas.
Salt Lake City	40 46	247 52	1850·0	15 34 E.	......	15·6 E.	......	......	......	......	U. S. Officers.
St. Peters	44 53	266 54	1823·0	10 29 E.	0 39 W.	9·8 E.	......	......	......	......	Long.
Prairie du Chien	43 01	268 51	1839·5	9 05 E.	0 06 W.	9·0 E.	73 17	......	73·3	13·83	Locke.
Brown's Settlement ...	42 02	268 54	1839·0	9 04 E.	0 06 W.	9·0 E.	72 21	......	72·4	13·76	Locke.
[illegible]	42 14	269 05	1839·0	......	......	......	72 44	......	72·7	13·76	Locke.
[illegible]	42 23	269 08	1839·5	8 45 E.	0 06 W.	8·7 E.	72 51	......	72·9	13·71	Locke.
[illegible]	43 03	269 08	1823·0	8 49 E.	0 39 W.	8·2 E.	......	......	......	......	Long.
Turkey River...........	42 42	269 12	1839·5	9 00 E.	0 06 W.	8·9 E.	73 11	......	73·2	13·71	Locke.
White Water River ...	42 18	269 22	1839·5	9 10 E.	0 06 W.	9·1 E.	72 55	......	72·9	13·80	Locke.
[illegible]	42 31	269 29	1839·5	8 30 E.	0 06 W.	8·4 E.	73 08	......	73·1	13·80	Locke.
[illegible]	42 30	269 34	1839·5	8 13 E.	0 06 W.	8·1 E.	71 55	......	71·9	13·76	Locke.
[illegible]	42 29	269 37	1839·5	8 22 E.	0 06 W.	8·3 E.	73 05	......	73·1	13·76	Locke.
Wabisipinicon River	41 44	269 37	1839·5	8 22 E.	0 06 W.	8·3 E.	72 15	......	72·3	13·86	Locke.
Farmers Creek	42 13	269 37	1840·5	9 08 E.	0 04 W.	9·1 E.	72 36	......	72·6	13·90	Locke.
Platteville	42 43	269 46	1841·5	......	......	......	73 17	......	73·3	......	Loomis.
Galina	42 28	269 47	1841·5	9 25 E.	0 02 W.	9·4 E.	73 03	......	73·1	......	Loomis.
Lostgrove	41 39	269 51	1840·0	8 10 E.	0 05 W.	8·1 E.	72 02	......	72·0	13·79	Locke.
Mineral Point	42 50	270 02	1839·5	8 40 E.	0 06 W.	8·6 E.	73 21	......	73·4 } 73·4	13·76	Locke.
			1841·5	......	......	......	73 23	......	73·4	......	Loomis.
Hickoks	42 58	270 13	1841·0	......	......	......	73 40	......	73·7	......	Loomis.
Blue Mound	43 01	270 22	1839·0	8 38 E.	0 06 W.	8·5 E.	73 41	......	73·7 } 73·6	13·82	Locke.
			1841·0	......	......	......	73 35	......	73·6	......	Loomis.
Pekin	40 35	270 24	1841·0	......	......	......	71 13	......	71·2	......	Loomis.
Campbells	43 01	270 34	1841·0	8 48 E.	0 03 W.	8·8 E.	73 28	......	73·5	......	Loomis.
Madison..................	43 04	270 54	1839·0	......	......	......	74 03	......	74·1 } 74·1	14·09	Locke.
			1841·0	7 30 E.	0 03 W.	7·5 E.	74 07	......	74·1	......	Loomis.
Peru	41 23	270 55	1841·5	......	......	......	71 51	...... }	71·9	......	Loomis.
			1841·5	......	......	......	71 50	......		......	Nicollet.
Juliet	41 30	271 09	1841·0	......	......	......	72 16	......	72·3	......	Nicollet.
Ottawa	41 15	271 10	1841·0	......	......	......	72 20	......	72·3	......	Nicollet.
Chicago	41 53	272 16	1841·0	......	......	......	72 48	......	72·8	......	Loomis.
			1841·0	......	......	......	72 46	......	72·8 } 72·7	......	Nicollet.
			1842·0	......	......	......	72 39	......	72·7	13·78	Younghusband.
St. Mary's	40 32	275 41	1845·0	3 04 E.	0 06 E.	3·2 E.	72 00	......	72·0	13·66	Locke.
Piqua	40 06	275 47	1840·0	......	......	......	71 36	......	71·6	13·61	Locke.
Urbana	40 05	276 12	1840·0	......	......	......	71 40	......	71·7	13·74	Locke.
Ann Arbor................	42 18	276 15	1840·0	......	......	......	73 15	......	73·2 } 73·2	......	Loomis.
			1843·0	......	......	......	73 14	......	73·2	13·84	Locke.
Ypsilanti	42 14	276 22	1841·0	......	......	......	73 18	......	73·3	......	Loomis.
Maumee..................	41 34	276 23	1839·0	......	......	......	72 49	......	72·8	......	Loomis.
Toledo	41 41	276 28	1839·0	......	......	......	73 06	......	73·1	......	Loomis.
Munroe	41 55	276 32	1841·0	......	......	......	73 26	......	73·4	......	Loomis.
Stoney Point	41 56	276 16	1848·0	2 07 E.	0 11 E.	2·3 E.	......	......	......	......	U. S. Engineers.
Amherstburg............	42 06	276 17	1845·0	......	......	......	73 30	......	73·5	13·79	Lefroy.
West Sister Island ...	41 44	276 51	1847·0	2 20 E.	0 09 E.	2·5 E.	......	......	......	......	U. S. Engineers.
Detroit	42 25	277 04	1840·5	1 56 E.	0 04 W.	1·9 E.	73 39	......	73·7	......	Locke.
			1841·0	......	......	......	73 33	......	73·5	......	Nicollet.
			1841·5	......	......	......	73 33	......	73·6	......	Nicollet.
			1842·0	......	......	......	73 29	......	73·5 } 73·6	13·82	Younghusband.
			1843·0	......	......	......	73 32	......	73·5	13·73 } 13·76	Locke.
			1845·0	......	......	......	73 39	......	73·7	13·72	Lefroy.
East Sister Island	41 49	277 09	1847·5	2 18 E.	0 10 E.	2·5 E.	......	......	......	......	U. S. Coast Survey.
Sandusky	41 29	277 13	1839·0	......	......	......	72 58	......	73·0	......	Loomis.
Kelly's Island	41 36	277 17	1846·0	2 13 E.	0 07 E.	2·3 E.	......	......	......	......	U. S. Coast Survey.
Port Sarnia	42 58	277 26	1845·0	......	......	......	74 16	......	74·3	13·81	Lefroy.
Huron	41 26	277 33	1843·0	......	......	......	73 00	......	73·0	13·75	Locke.
Frazerburg...............	40 09	277 52	1841·0	......	......	......	71 49	......	71·8	......	Loomis.
Goderich	43 45	278 08	1845·0	......	......	......	75 05	......	75·1	13·84	Lefroy.
Brooklyn	41 30	278 17	1841·0	......	......	......	73 16	......	73·3	......	Loomis.
Cleveland	41 30	278 18	1840·0	1 19 E.	0 05 W.	1·2 E.	73 04	......	73·1	......	Loomis.
			1842·0	......	......	......	73 04	......	73·1 } 73·1	13·67 } 13·73	Younghusband.
			1843·0	......	......	......	73 08	......	73·1	13·80	Locke.

ZONE I.—Lat. 40° to 45° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.		Inclination. Observed.	Inclination. Correction to Epoch 1842·5.	Inclination. Corrected.		Force in British units.		Observers.
	° ′	° ′		° ′	° ′	°		° ′	′	°				
Clinton	40 58	278 20	1841·0	......	......	......		72 11	......	72·7		......		Loomis.
Fulton	40 55	278 22	1841·0	......	......	......		72 39	......	72·7		......		Loomis.
Bedford	41 24	278 28	1840·0	......	......	......		72 58	......	73·0		......		Loomis.
Dover	40 33	278 30	1841·0	1 56 E.	0 05 W.	1·9 E.		72 19	......	72·3		......		Loomis.
Tallmadge	41 06	278 33	1840·5	......	......	......		72 51	......	72·9		......		Loomis.
Boston	41 15	278 31	1840·0	1 52 E.	0 04 W.	1·8 E.		72 49	......	72·8		......		Loomis.
Twinsburgh	41 20	278 31	1840·0	......	......	......		72 51	......	72·9		......		Loomis.
Aurora	41 20	278 19	1840·0	......	......	......		72 56	......	72·9		......		Loomis.
Streetsborough	41 15	278 40	1840·0	......	......	......		72 53	......	72·9		......		Loomis.
Shalersville	41 15	278 47	1840·0	......	......	......		72 57	......	73·0		......		Loomis.
Windham	41 15	278 57	1840·0	......	......	......		73 03	......	73·1		......		Loomis.
Ashtabula	41 52	279 08	1841·0	......	......	......		72 25	......	72·4		14·01		Locke.
Warren	41 16	279 11	1840·0	......	......	......		73 01	......	73·0	73·0	......		Loomis.
			1841·5	......	......	......		73 00	......	73·0		......		Bache.
			1844·0	......	......	......		72 56	......	72·9		13·66		Locke.
Ashtabula Landing	41 51	279 13	1841·5	......	......	......		72 24	......	72·4		......		Bache.
Wheeling	40 08	279 13	1840·5	......	......	......		72 09	......	72·2	72·2	......		Bache.
			1845·0	2 01 E.	0 07 E.	2·2 E.		72 11	......	72·2		13·72		Locke.
Bezetta	41 20	279 15	1840·0	......	......	......		73 00	......	73·0		......		Loomis.
Wellsville	40 38	279 16	1841·0	......	......	......		72 35	......	72·6		13·58		Locke.
Steubenville	40 25	279 21	1840·5	......	......	......		72 33	......	72·6		......		Bache.
Kinsman	41 30	279 26	1840·0	......	......	......		73 08	......	73·1		......		Loomis.
Hartford	41 19	279 26	1840·0	......	......	......		73 00	......	73·0		......		Loomis.
Beaver	40 44	279 33	1839·0	......	......	......		72 40	......	72·7		......		Loomis.
Economy	40 37	279 41	1840·5	......	......	......		72 35	......	72·6		......		Bache.
Mercer	41 14	279 44	1841·5	0 51 E.	0 03 W.	0·8 E.		72 57	......	73·0		13·64		Bache.
Hudson	41 15	279 45	1839·5	......	......	......		72 47	......	72·8		......		Loomis.
Erie	42 08	279 54	1841·5	0 30 W.	0 03 W.	0·6 W.	0·6 W.	73 47	......	73·8	73·8	13·57	13·50	Bache.
			1862·5	1 33 W.	1 00 E.	0·6 W.		73 52	−04	73·8		13·42		Schott.
Pittsburg	40 32	279 58	1839·0	......	......	......		72 39	......	......		......		Loomis.
			1840·5	0 08 W.	0 06 W.	0·2 W.		72 32	......	72·7		13·49		Bache.
			1842·5	......	......	......		72 44	......	......		......		Locke.
			1845·5	0 33 W.	0 09 E.	0·4 W.		72 47	......	......		......		
Penetanquishene	44 49	279 59	1844·0	......	......	......		76 20	......	76·3		14·08		Locke.
			1848·5	1 28 W.	0 18 E.	1·2 W.		......	......	......		......		Lieut. Typen, R.N.
Mean of 7 Stations	41 48	280 03	1841·0	......	......	......		73 31	......	73·5		......		Loomis.
Hamilton	43 16	280 04	1843·5	......	......	......		74 55	......	74·9		......		Lefroy.
Mean of 7 Stations	40 15	280 05	1841·0	......	......	......		72 13	......	72·2		......		Loomis.
Brownsville	40 00	280 12	1840·5	......	......	......		71 54	......	71·9	71·9	13·54	13·45	Bache.
			1862·5	1 14 W.	1 00 E.	0·2 W.		71 57	−04	71·9		13·35		Schott.
Berlin's Tavern	41 16	280 24	1844·5	......	......	......		72 53	......	72·9		......		Bache.
Dunkirk	42 29	280 37	1841·5	0 53 W.	0 03 W.	0·9 W.		74 17	......	74·3		......		Bache.
Toronto Observatory	43 39	280 39	1842·5	1 21 W.	......	1·4 W.		75 15	......	75·3		13·90		Observatory.
Niagara	43 05	280 51	1841·0	......	......	......		74 52	......	74·9		......		Nicollet.
			1842·5	......	......	......		74 51	......	74·9		13·64		Bache.
			1845·5	......	......	......		74 47	......	74·8		13·79		Lefroy.
Armagh	40 29	280 56	1843·5	......	......	......		72 19	......	72·3		......		Bache.
Buffaloe	42 53	281 06	1839·5	......	......	......		74 41	......	74·7		......		Loomis.
			1844·5	......	......	......		74 37	......	74·6		13·81		Locke.
			1845·5	1 25 W.	0 09 E.	1·3 W.		74 37	......	74·6		13·73		Lefroy.
Lockport	43 11	281 14	1844·5	......	......	......		74 44	......	74·7		13·68		Locke.
Ellicotville	42 30	281 16	1841·5	2 36 W.	0 03 W.	2·7 W.		74 18	......	74·3		13·77		Bache.
Carwinsville	40 58	281 24	1841·5	1 45 W.	0 03 W.	1·8 W.		72 50	......	72·8		13·55		Bache.
Alleghany Summit	40 27	281 50	1845·5	......	......	......		72 27	......	72·5		13·62		Locke.
Belvidere	42 13	281 54	1841·5	......	......	......		74 10	......	74·2		......		Bache.
Huntingdon	40 31	281 58	1840·5	1 52 W.	0 06 W.	2·0 W.		72 18	......	72·3		13·51		Bache.
Rochester	43 08	282 09	1843·5	......	......	......		74 44	......	74·7	74·7	......		Bache.
			1844·5	......	......	......		74 39	......	74·7		13·67		Locke.
Bellefonte	40 55	282 11	1841·5	......	......	......		72 42	......	72·7		......		Bache.
Heiner's Run	41 22	282 12	1856·5	3 19 W.	0 42 E.	2·6 W.		......	......	......		......		U. S. Coast Survey.
Mean of 6 Stations	43 12	282 21	1844·0	......	......	......		74 53	......	74·9		......		Loomis.

ZONE I.—Lat. 40° to 45° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.	Inclination. Observed.	Inclination. Correction to Epoch 1842·5.	Inclination. Corrected.	Force in British units.	Observers.
	° ′	° ′		° ′	° ′	°	° ′	′	°		
Lewiston	40 35	282 24	1840·5	......	......	......	72 30	......	72·5	......	Bache.
Bath	42 21	282 39	1841·5	3 31 w.	0 03 w.	3·6 w. } 3·7 w.	74 28	...... }	74·4	13·72 } 13·64	Bache.
			1862·5	4 48 w.	1 00 E.	3·8 w.	74 26	−04		13·56	Schott.
Mean of 10 Stations	41 25	282 43	1841·5	......	......	......	73 18	......	73·3	......	Loomis.
Geneva	42 53	282 58	1843·5	......	......	......	74 33	......	74·6	13·63	Bache.
Williamsport	41 14	282 58	1841·5	3 31 w.	0 03 w.	3·6 w. } 3·5 w.	72 54	...... }	72·9	13·55 } 13·43	Bache.
			1862·5	4 26 w.	1 00 E.	3·4 w.	72 51	−04		13·31	Schott.
Duncan's Island	40 25	282 59	1840·5	......	......	......	72 35	......	72·6	......	Bache.
Harrisburg	40 16	283 07	1840·5	3 13 w.	0 06 w.	3·3 w. } 3·0 w.	72 21	...... }	72·4	13·44 } 13·40	Bache.
			1862·5	3 45 w.	1 00 E.	2·8 w.	72 32	−04		13·36	Schott.
Cumberland	40 13	283 10	1844·5	......	......	......	71 36	......	71·6	13·54	Locke.
Oswego	43 26	283 24	1839·5	......	......	......	75 11	...... }	75·2	......	Loomis.
			1843·5	......	......	......	75 07	......		......	Bache.
			1845·5	......	......	......	75 08	......		......	Nicollet.
Kingston	44 13	283 25	1842·5	......	......	......	77 19	...... }	77·3	......	Lefroy.
			1845·5	......	......	......	77 14	......		......	Younghusband.
Owego	42 08	283 43	1841·5	......	......	......	74 14	......	74·2	......	Bache.
Syracuse	43 03	283 51	1839·5	......	......	......	74 51	...... }	74·9	......	Loomis.
			1843·5	......	......	......	74 51	......		13·61	Bache.
Silverlake	41 57	283 58	1841·5	4 30 w.	0 03 w.	4·6 w.	73 42	......	73·7	13·47	Bache.
Wilkesbarre	41 14	284 02	1841·5	......	......	......	73 10	......	73·2	......	Bache.
Reading	40 19	284 05	1840·5	......	......	......	72 32	......	72·5	......	Bache.
Brockville	44 35	284 15	1845·5	......	......	......	76 19	......	76·3	13·71	Younghusband.
Whitehill	40 08	284 17	1846·5	4 22 w.	0 12 E.	4·2 w.	......	......	......	......	U. S. Coast Survey.
Fort Delaware	40 05	284 26	1846·5	3 13 w.	0 12 E.	3·0 w.	......	......	......	......	U. S. Coast Survey.
Easton	40 42	284 45	1841·5	3 38 w.	0 03 w.	3·7 w.	72 39	......	72·7	......	Bache.
Utica	43 05	284 46	1839·5	......	......	......	74 57	...... }	74·9	......	Loomis.
			1843·5	......	......	......	74 50	......		......	Bache.
			1844·5	......	......	......	74 49	......		13·69	Locke.
Doylestown	40 18	284 50	1841·5	......	......	......	72 23	......	72·4	......	Bache.
Williamsburg	44 55	284 53	1843·5	......	......	......	76 30	......	76·5	......	Lefroy.
Bushkill	41 07	284 58	1841·5	......	......	......	73 31	......	73·5	......	Bache.
Vanuxem	40 07	285 07	1846·5	4 22 w.	0 12 E.	4·2 w.	72 22	......	72·4	13·43	Locke.
Milford	41 19	285 08	1841·5	......	......	......	73 48	......	73·8	13·50	Bache.
Bristol	40 06	285 13	1842·5	......	......	......	72 25	......	72·4	13·38	Locke.
White Hill	40 08	285 16	1846·5	4 22 w.	0 12 E.	4·2 w.	72 06	......	72·1	13·50	Locke.
Mount Rose	40 22	285 17	1852·5	5 32 w.	0 30 E.	5·0 w.	72 43	......	72·7	13·90	U. S. Coast Survey.
Trenton	40 13	285 20	1841·5	......	......	......	71 59	......	72·0	13·55	Locke.
Princeton	40 22	285 20	1839·5	......	......	......	72 47	...... }	72·7	...... } 13·52	Loomis.
			1842·5	......	......	......	72 44	......		13·50	Lefroy.
			1843·5	......	......	......	72 40	......		13·55	Locke.
New Brunswick	40 30	285 25	1844·5	......	......	......	72 43	......	72·7	13·51	Locke.
Mean of [illegible] Stations	41 12	285 35	1843·5	......	......	......	73 48	......	73·8	......	Loomis.
Cole	40 32	285 46	1846·5	5 38 w.	0 12 E.	5·4 w.	72 34	......	72·6	13·44	Locke.
Newark	40 45	285 53	1841·5	......	......	......	72 49	...... }	72·8	13·50 } 13·48	Locke.
			1844·5	......	......	......	72 48	......		......	Locke.
			1846·5	5 35 w.	0 12 E.	5·4 w.	72 52	......		13·46	U. S. Coast Survey.
New York, Lunatic Asylum	40 49	285 57	1822·5	......	......	......	73 00	...... }	72·7	13·57 } 13·49	Sabine.
			1841·5	......	......	......	72 40	......		13·48	Locke.
			1842·0	......	......	......	72 40	......		......	Bache.
			1842·5	......	......	......	72 40	......		13·44	Lefroy.
			1844·5	......	......	......	72 42	......		13·48	Locke.
			1844·5	......	......	......	72 49	......		......	Renwick.
New York, Columbia College	40 43	285 59	1834·5	......	......	......	72 52	...... }	72·8	...... } 13·55	Bache.
			1839·5	......	......	......	72 52	......		......	Loomis.
			1841·5	......	......	......	72 41	......		13·51	Locke.
			1844·5	6 13 w.	0 06 E. }	6·1 w. } 6·2 w.	72 38	......		13·64	Renwick.
			1844·5	......	......		72 43	......		13·51	Locke.
			1845·5	6 25 w.	0 09 E.	6·3 w.	72 41	......		......	Renwick.
Governor's Island	40 42	285 59	1855·5	6 40 w.	0 39 E.	6·0 w.	72 46	−03	72·7	13·25	U. S. Coast Survey.

ZONE I.—Lat. 40° to 45° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.	Inclination. Observed.	Inclination. Correction to Epoch 1842·5.	Inclination. Corrected.	Force in British units.	Observers.
	° ′	° ′		° ′	° ′	°	° ′	′	°		
West Point	41 24	285 59	1834·5	......	......	......	73 27	......	73·4	......	Bache.
			1839·5	......	......	......	73 27	......		......	Loomis.
			1840·5	......	......	......	73 20	......		......	Graham.
			1842·5	......	......	......	73 25	......		......	Bache.
			1842·5	......	......	......	73 30	......		13·67	Lefroy.
Sandy Hook	40 28	286 00	1844·5	5 51 w.	0 06 E.	5·8 w. } 5·7 w.	72 38	......	72·7	13·66 } 13·48	Renwick.
			1855·5	6 11 w.	0 39 E.	5·6 w.	72 52	−03		13·30	U. S. Coast Survey.
Mount Prospect	40 40	286 02	1846·5	5 55 w.	0 12 E.	5·7 w. } 5·8 w.	72 28	......	72·6	13·45 } 13·53	Locke.
			1860·5	6 44 w.	0 54 E.	5·8 w.	72 41	−04		13·61	U. S. Coast Survey.
Cold Spring	41 25	286 03	1855·5	5 34 w.	0 39 E.	4·9 w.	73 55	−03	73·9	13·68	U. S. Coast Survey.
Bloomingdale Asylum	40 49	286 03	1846·5	5 10 w.	0 12 E.	5·0 w.	72 39	......	72·7	13·44	Locke.
Schenectady	42 48	286 04	1839·5	......	......	......	74 36	......	74·8	......	Loomis.
			1843·5	......	......	......	74 55	......		13·45	Bache.
Powkeepsie	41 41	286 05	1844·5	......	......	......	74 05	......	74·1	13·52	Locke.
Legget	40 49	286 07	1847·5	5 41 w.	0 15 E.	5·4 w.	72 53	......	72·9	13·51	U. S. Coast Survey.
New Rochelle	40 53	286 13	1844·5	5 30 w.	0 06 E.	5·4 w.	72 44	......	72·7	12·95	U. S. Coast Survey.
Albany and Greenbush	42 40	286 16	1841·5	......	......	......	74 40	......	74·7	......	Bache.
			1841·5	......	......	......	74 40	......		......	Nicollet.
			1842·5	......	......	......	74 45	......		13·60 } 13·58	Lefroy.
			1844·5	......	......	......	74 40	......		13·56	Locke.
Saw Pits	41 00	286 21	1844·5	5 58 w.	0 06 E.	5·9 w.	72 53	......	72·9	......	U. S. Coast Survey.
Stamford	41 04	286 28	1844·5	6 36 w.	0 06 E.	6·5 w.	73 02	......	73·0	13·32	U. S. Coast Survey.
Oyster Bay	40 53	286 29	1844·5	6 54 w.	0 06 E.	6·8 w.	72 59	......	73·0	13·23	Renwick and U. S. Coast Survey.
Lloyd's Harbour	40 56	286 35	1844·5	6 12 w.	0 06 E.	6·1 w.	72 51	......	72·9	13·08	U. S. Coast Survey.
Norwalk	41 07	286 36	1844·5	6 49 w.	0 06 E.	6·7 w.	73 10	......	73·2	......	U. S. Coast Survey.
Tashua	41 16	286 45	1863·5	8 03 w.	1 03 E.	7·0 w.	73 01	−04	73·0	13·26	U. S. Coast Survey.
Ivy Hill	41 52	286 47	1863·5	8 26 w.	1 03 E.	7·4 w.	73 32	−04	73·5	13·41	U. S. Coast Survey.
Blackrock	41 09	286 47	1845·5	6 54 w.	0 09 E.	6·8 w.	......	......	......	......	[illegible]
Bridgeport	41 11	286 48	1845·5	6 19 w.	0 09 E.	6·2 w.	73 21	......	73·4	13·05	[illegible]
Fire Island	40 38	286 48	1860·5	7 46 w.	0 54 E.	6·9 w.	73 00	−04	72·9	13·34	[illegible]
Burlington	44 28	286 50	1845·5	9 22 w.	0 09 E.	9·2 w. } 9·2 w.	75 37	......	75·6 } 75·7	14·19	U. S. Coast Survey.
			1855·5	9 57 w.	0 39 E.	9·3 w.	75 57	−03	75·9		
Drowned Meadow	40 56	286 56	1845·5	6 04 w.	0 09 E.	5·9 w.	......	......	......	......	U. S. Coast Survey.
Newhaven	41 18	287 02	1839·5	6 13 w.	0 09 w.	6·4 w. } 6·3 w.	73 27	......	73·5	13·35 } 13·37	Loomis.
			1842·5	......	......	......	73 30	......		13·42	Locke.
			1842·5	......	......	......	73 27	......		13·42	Lefroy.
			1844·5	......	......	......	73 21	......		13·33	Renwick.
			1845·5	6 17 w.	0 09 E.	6·1 w.	......	......		......	U. S. Coast Survey.
			1848·5	6 38 w.	0 18 E.	6·3 w.	73 32	......		13·29	U. S. Coast Survey.
Oyster Point	41 17	287 05	1848·5	6 32 w.	0 18 E.	6·2 w. } 6·3 w.	73 33	−01	73·6	13·29 } 13 24	U. S. Coast Survey.
			1855·5	7 03 w.	0 39 E.	6·4 w.	73 45	−03		13·19	U. S. Coast Survey.
Rutland	43 36	287 05	1859·5	9 49 w.	0 51 E.	9·0 w.	75 20	−03	75·3	13·68	U. S. Coast Survey.
Fort Wooster	41 17	287 07	1848·0	7 26 w.	0 18 E.	7·1 w.	74 15	−01	74·2	13·40	U. S. Coast Survey.
Chesterfield	42 24	287 09	1859·5	8 54 w.	0 51 E.	8·1 w.	74 21	−03	74·3	13·60	U. S. Coast Survey.
Sachem's Head	41 17	287 17	1845·5	6 15 w.	0 09 E.	6·1 w.	......	......	......	......	U. S. Coast Survey.
Hartford	41 46	287 19	1839·5	......	......	......	73 58	......	74·0	13·58 } 13·58	Loomis.
			1859·5	......	......	......	74 07	−03		13·58	U. S. Coast Survey.
Longmeadow	42 02	287 24	1839 5	......	......	......	74 05	......	74·1	......	Loomis.
Deerfield	42 33	287 21	1859·5	9 25 w.	0 51 E.	8·6 w.	74 35	−03	74·5	13·61	U. S. Coast Survey.
Springfield	42 06	287 28	1835·0	......	......	......	......	......	......	13·65	Bache.
			1839·5	8 39 w.	0 09 w.	8·8 w. } 8·3 w.	74 07	......	74·2	...... } 13·62	Loomis.
			1841·5	......	......	......	74 11	......		......	Bache.
			1859·5	8 39 w.	0 51 E.	7·8 w.	74 15	−03		13·60	U. S. Coast Survey.
Box Hill	41 48	287 35	1862·0	8 30 w.	1 00 E.	7·5 w.	73 58	−04	73·9	13·50	U. S. Coast Survey.
Greenport	41 06	287 38	1845·5	7 14 w.	0 09 E.	7·1 w.	72 58	......	73·0	13·14	Renwick.
Saybrook	41 16	287 40	1845·5	6 50 w.	0 09 E.	6·7 w.	74 34	......	74·6	......	U. S. Coast Survey.
Sag Harbour	41 00	287 43	1860·5	8 28 w.	0 54 E.	7·6 w.	73 21	−03	73·3	13·62	U. S. Coast Survey.
Troy Village	42 50	287 49	1861·5	9 03 w.	0 57 E.	8·1 w.	74 46	−01	74·7	13·89	U. S. Coast Survey.
Bald Hill	41 58	287 49	1861·5	8 50 w.	0 57 E.	7·9 w.	73 59	−04	73·9	13·43	U. S. Coast Survey.
Groton Point	41 18	288 00	1845·5	7 30 w.	0 09 E.	7·4 w.	......	......	......	......	U. S. Coast Survey.
Warren	43 56	288 05	1830·5	9 08 w.	0 36 w.	9·7 w.	......	......	......	......	Graham.

ZONE I.—Lat. 40° to 45° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Ob-served.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.		Inclination. Ob-served.	Inclination. Correction to Epoch 1842·5.	Inclination. Corrected.	Force in British units.		Observers.
	° ′	° ′		° ′	° ′	°		° ′	′	°			
Stonington	41 20	288 05	1845·0	7 38 w.	0 03 E.	7·5 w.		73 25	......	73·4	13·13		Renwick.
West Rumney	43 49	288 07	1839·5	9 38 w.	0 36 w.	10·2 w.		......	......	......	......		Graham.
Wachusett	42 29	288 07	1860·5	8 48 w.	0 54 E.	7·9 w.		74 29	−03	74·4	13·54		U. S. Coast Survey.
Watch Hill	41 19	288 09	1847·5	7 33 w.	0 15 E.	7·3 w.		......	......	......	......		U. S. Coast Survey.
Worcester	42 16	288 12	1839·5	......	......	......		74 21	......	74·4	......		Loomis.
Plymouth	43 45	288 18	1830·5	8 32 w.	0 36 w.	9·1 w.		......	......	......	......		Graham.
Mount Uncanoonuc	42 59	288 25	1848·5	9 04 w.	0 18 E.	8·8 w.		75 09	−01	75·1	13·51		U. S. Coast Survey.
Spencer Hill	41 41	288 31	1844·5	9 06 w.	0 06 E.	9·0 w.		75 07	......	75·1	......		U. S. Coast Survey.
Lake Winninsissiogee	44 43	288 31	1830·5	7 53 w.	0 36 w.	8·5 w.		......	......	......	......		Graham.
Near Mt. Washington	44 16	288 31	1845·5	11 31 w.	0 09 E.	11·4 w.		75 40	......	75·7	13·47		Locke.
Point Judeth's Light	41 22	288 31	1847·5	9 00 w.	0 15 E.	8·8 w.		73 45	−01	73·7	13·54		U. S. Coast Survey.
McSparran's Hill	41 30	288 33	1844·5	8 49 w.	0 06 E.	8·7 w.		73 48	......	73·8	......		U. S. Coast Survey.
Beacon Pole Hill	42 00	288 33	1844·5	9 27 w.	0 06 E.	9·3 w.		74 22	......	75·4	......		U. S. Coast Survey.
Providence	41 49	288 35	1839·5	......	......	......		74 00	......		13·41		Loomis.
			1841·5	......	......	......		74 03	......		......		Bache.
			1842·5	......	......	......		74 00	......	74·1	13·48	13·38	Lefroy.
			1855·5	9 32 w.	0 39 E.	8·9 w.		74 16	−03		13·24		U. S. Coast Survey.
Gunstock	43 31	288 38	1860·5	10 54 w.	0·54 E.	10·0 w.		75 44	−03	75·7	13·80		U. S. Coast Survey.
Goreham	44 27	288 47	1845·5	......	......	......		75 33	......	75·6	13·58		Locke.
Patuccawa	43 07	288 48	1849·5	10 43 w.	0 21 E.	10·4 w.		76 50	−01	76·8	13·26		U. S. Coast Survey.
Cambridge	42 22	288 52	1839·5	......	......	......		74 20	......		......		Loomis.
			1841·5	9 15 w.	0 03 w.	9·3 w.		74 17	......		......		Graham and Bond.
			1842·5	......	......	......		74 15	......	74·3	13·47		Locke.
			1842·5	......	......	......		74 20	......		13·50	13·45	Lefroy.
			1845·5	......	......	......		74 19	......		13·39		Locke.
Blue Hill	42 13	288 53	1845·5	9 14 w.	0 09 E.	9·1 w.		75 06	......	75·1	13·68		U. S. Coast Survey.
Dorchester	42 19	288 55	1842·5	......	......	......		74 13	......	74·2	......		Lefroy.
Copecut Hill	41 43	288 57	1844·5	9 09 w.	0 06 E.	9·1 w.		74 10	......	74·2	......		U. S. Coast Survey.
Dorchester Heights	42 20	288 58	1846·5	9 31 w.	0 12 E.	9·3w.	9·5w.	74 13	−01	74·3	13·19	[illegible]	U. S. [illegible]
			1855·5	10 14 w.	0 39 E.	9·6w.		74 30	−03		13·26		U. [illegible]
Croton Point	41 19	288 59	1844·5	7 29 w.	0 06 E.	7·4 w.		......	......	......	......		B[illegible]
Boston	42 22	289 01	1839·5	......	......	......		......	......		13·39		Loomis.
			1841·5	......	......	......		74 09	......		......		Graham.
			1842·5	......	......	......		74 06	......	74·1	13·37	13·34	Locke.
			1855·5	......	......	......		......	......	......	13·26		U. S. Coast Survey.
Little Nehant	42 26	289 04	1849·5	9 41 w.	0 21 E.	9·3 w.		74 30	−01	74·5	13·30		U. S. Coast Survey.
Fort Point	41 38	289 05	1845·5	8 57 w.	0 09 E.	8·8 w.		......	......	......	......		U. S. Coast Survey.
Nantasket	42 18	289 06	1847·5	9 37 w.	0 15 E.	9·4 w.		74 16	−01	74·3	13·16		U. S. Coast Survey.
Fairhaven	41 37	289 06	1845·5	8 54 w.	0 09 E.	8·8 w.		74 40	......	74·7	13·58		U. S. Coast Survey.
Fort Lee	42 32	289 08	1849·5	10 15 w.	0 21 E.	9·9w.	10·0w.	......	......	......	......		U. S. Coast Survey.
			1855·5	10 50 w.	0 39 E.	10·2w.		75 37	−02	75·6	14·01		U. S. Coast Survey.
Codden's Hill	42 31	289 09	1849·5	11 50 w.	0 21 E.	11·5 w.		......	......	......	......		U. S. Coast Survey.
[illegible]	41 27	289 09	1845·5	11 50	0 09 E.	11·7 w.		75 51	......	75·9	13·54		Locke.
Ipswich	42 41	289 10	1859·5	11 11 w.	0 51 E.	10·4 w.		74 37	−03	74·6	13·57		U. S. Coast Survey.
Plum Island	42 48	289 11	1850·5	10 06 w.	0 24 E.	9·7w.	9·9w.	74 55	−02	74·9	13·57	13·55	U. S. Coast Survey.
			1859·5	10 58 w.	0 51 E.	10·1w.		74 53	−03		13·53		U. S. Coast Survey.
Mount Pleasant	41 02	289 11	1851·5	14 32 w.	0 27 E.	14·1 w.		76 02	−02	76·0	13·30		U. S. Coast Survey.
Baker's Island Light	42 32	289 13	1849·5	12 17 w.	0 21 E.	11·9 w.		74 19	−01	74·3	13·52		U. S. Coast Survey.
Tarpaulin Cove	41 28	289 15	1846·5	9 12 w.	0 12 E.	9·0 w.		73 50	......	73·8	13·28		U. S. Coast Survey.
Boiling Rock	43 05	289 15	1844·5	9 47 w.	0 06 E.	9·7 w.		74 51	......	74·9	......		B. [illegible] Survey.
Portsmouth	43 03	289 16	1844·5	......	......	......		74 51	......	74·9	......		Graham and Whipple.
Locke's Mills	44 21	289 16	1845·5	12 08 w.	0 09 E.	12·0 w.		75 51	......	75·9	13·52		Locke.
Kittery Point	43 05	289 17	1850·5	10 30 w.	0 24 E.	10·1w.	10·3w.	74 57	−02	75·0	13·48	13·53	U. S. Coast Survey.
			1859·5	11 15 w.	0 51 E.	10·6w.		75 04	−03		13·57		U. S. Coast Survey.
Thompson	42 37	289 17	1859·5	11 09 w.	0 51 E.	10·3 w.		74 30	−03	74·5	13·75		U. S. Coast Survey.
Mount Agamenticus	43 13	289 19	1847·5	10 10 w.	0 15 E.	9·9 w.		74 55	−01	74·9	13·28		U. S. Coast Survey.
Annis Quam	42 39	289 20	1849·5	11 37 w.	0 21 E.	11·3 w.		......	......	......	......		U. S. Coast Survey.
			1859·5	......	......	......		74 56	−03	74·9	13·81		U. S. Coast Survey.
Beacon Hill	42 36	289 22	1849·5	11 21 w.	0 21 E.	11·0w.	11·1w.	74 26	−01	74·6	13·48	13·67	U. S. Coast Survey.
			1859·5	12 03 w.	0 51 E.	11·2w.		74 46	−03		13·86		U. S. Coast Survey.
Indian Hill	41 28	289 22	1846·0	8 46 w.	0 12 E.	8·6 w.		73 35	−01	73·6	13·20		U. S. Coast Survey.

ZONE I.—Lat. 40° to 45° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.		Inclination. Observed.	Inclination. Correction to Epoch 1842·5.	Inclination. Corrected.	Force in British units.		Observers.
	° ′	° ′		° ′	° ′	°		° ′	′	°			
Isle of Shoals	42 59	289 23	1847·5	10 04 w.	0 15 E.	9·8 w.		74 44	−01	74·7	13·22		U. S. Coast Survey.
Cape Neddick	43 12	289 24	1851·5	11 09 w.	0 27 E.	10·7 w.		74 58	−02	74·9	13·56		U. S. Coast Survey.
Rockport	42 40	289 24	1859·5	11 37 w	0 51 E.	10·8 w		75 06	−03	75·1	13·72		U. S. Coast Survey.
Mahomet Hill	41 56	289 25	1845·5	9 17 w.	0 09 E.	9·1 w.		74 30	......	74·3	13·52		U. S. Coast Survey.
			1846·5	......	......	......		74 01	......		......		U. S. Coast Survey.
Sampson's Hill.........	41 23	289 31	1846·5	8 49 w.	0 12 E.	8·6 w.		73 25	......	73·4	13·15		U. S. Coast Survey.
Kennebunk	43 21	289 32	1851·5	11 24 w.	0 27 E.	11·0 w.		75 14	−02	75·2	13·53		U. S. Coast Survey.
Shootflying Hill	41 41	289 39	1845·5	9 38 w.	0 09 E.	9·5 w.		74 10	......	74·2	13·42		U. S. Coast Survey.
Fletchersneck	43 27	289 40	1850·5	11 18 w.	0 24 E.	10·9 w.		75 18	−02	75·3	13·56		U. S. Coast Survey.
Mount Independence..	43 46	289 41	1849·5	11 46 w.	0 21 E.	11·4 w.		75 24	−01	75·4	13·33		U. S. Coast Survey.
Hyannis.................	41 38	289 42	1846·5	9 22 w.	0 12 E.	9·2 w.		73 49	......	73·8	13·21		U. S. Coast Survey.
Portland	43 39	289 44	1845·5	11 28 w.	0 09 E.	11·3 w.	° 11·3 w.	75 13	......	75·2	13·44	13·36	Locke.
			1851·5	11 41 w.	0 27 E.	11·2 w.		75 14	−02		13·54		U. S. Coast Survey.
			1859·5	12 20 w.	0 51 E.	11·5 w.		......	......		13·30		U. S. Coast Survey.
			1863·5	12 18 w.	1 03 E.	11·3 w.		75 05	−04		13·16		U. S. Coast Survey.
Richmond Island	43 33	289 46	1850·5	12 18 w.	0 24 E.	11·9 w.		75 08	−02	75·1	13·50		U. S. Coast Survey.
Provincetown	42 03	289 48	1835·5	9 20 w.	0 21 w.	9·7 w.	10·1 w.	......	......	......	......		Graham.
			1860·5	11 24 w.	0 54 E.	10·5 w.		74 10	−04	74·1	13·40		U. S. Coast Survey.
Nantucket	41 18	289 54	1846·5	9 14 w.	0 12 E.	9·0 w.	9·2 w.	73 44	−01	73·9	13·05	13·10	U. S. Coast Survey.
			1855·5	9 58 w.	0 39 E.	9·3 w.		74 01	−03		13·16		U. S. Coast Survey.
Freeport	43 51	289 54	1863·5	14 12 w.	1 03 E.	13·2 w.		75 20	−04	75·3	13·27		U. S. Coast Survey.
Mount Sebattis	44 09	289 55	1853·5	12 54 w.	0 33 E.	12·4 w.		75 41	−02	75·7	13·80		U. S. Coast Survey.
Wellfleet..................	41 56	289 59	1860·5	10 44 w.	0 54 E.	9·8 w.		74 20	−04	74·3	13·48		U. S. Coast Survey.
Chatham Lights	41 40	290 03	1860·5	11 12 w.	0 54 E.	10·3 w.		73 46	−04	73·7	13·39		U. S. Coast Survey.
Cape Small	43 47	290 10	1851·5	12 06 w.	0 27 E.	11·7 w.		75 02	−02	75·0	13·11		U. S. Coast Survey.
Bath	43 55	290 11	1863·5	12 52 w.	1 03 E.	11·8 w.		75 26	−04	75·4	13·19		U. S. Coast Survey.
Ragged Mountain......	44 13	290 51	1854·5	14 17 w.	0 36 E.	13·7 w.		75 41	−02	75·7	13·50		U. S. Coast Survey.
Mount Harris	44 40	290 51	1855·5	14 35 w.	0 39 E.	13·9 w.		76 14	−03	76·2	13·60		U. S. Coast Survey.
Rockland	44 06	290 54	1863·5	15 02 w.	1 03 E.	14·0 w.		75 31	−04	75·5	13·13		U. S. Coast Survey.
Camden	44 12	290 55	1854·5	13 57 w.	0 36 E.	13·4 w.		75 42	−02	75·7	13·52		U. S. Coast Survey.
Belfast	44 26	291 00	1863·5	15 30 w.	1 03 E.	14·5 w.		75 38	−04	75·6	13·28		U. S. Coast Survey.
Bangor	44 48	291 13	1841·5	......	......	......		76 12	......	76·1	......		[illegible]
			1857·5	15 20 w.	0 45 E.	14·6 w.		76 13	−03		13·53	13·36	[illegible]
			1863·5	......	......	......		76 05	−04		13·20		[illegible]
Mount Saunders	44 39	291 24	1856·5	14 59 w.	0 42 E.	14·3 w.		75 59	−03	75·9	13·48		[illegible]
Mount Desert	44 21	291 47	1856·5	15 14 w.	0 42 E.	14·5 w.		76 09	−03	76·1	13·61		[illegible]
Humpback Mount ...	44 52	291 54	1858·5	15 48 w.	0 48 E.	15·0 w.		76 12	−03	76·2	13·52		[illegible]
At sea.....................	41 06	292 04	1841·5	10 08 w.	0 03 w.	10·2 w.		......	......	......	......		[illegible]
Western Ridge	44 59	292 32	1859·5	16 32 w.	0 51 E.	15·7 w.		76 20	−03	76·3	13·44		[illegible]
At sea.....................	41 04	293 10	1841·5	11 55 w.	0 03 w.	12·0 w.		......	......	......	......		[illegible]
Waterville...............	44 33	293 23	1847·5	......	......	......		75 58	−01	76·0	13·28		Keely.
Annapolis	44 45	294 04	1847·5	......	......	......		75 42	−01	75·7	......		Keely.
Bridgetown	44 51	294 22	1847·5	......	......	......		75 41	−01	75·7	13·07		Keely.
At sea.....................	41 29	294 22	1841·5	12 27 w.	......	12·5 w.		......	......	......	......		Barnett.
At sea.....................	41 28	294 57	1841·5	13 05 w.	......	13·1 w.		......	......	......	......		Barnett.
Hiltz	44 57	295 09	1847·5	......	......	......		75 37	−01	75·6	......		Keely.
At sea.....................	41 28	295 34	1841·5	13 08 w.	......	13·4 w.		......	......	......	......		Barnett.
Halifax	44 39	296 23	1838·5	......	......	......	17·9 w.	74 45	......	75·2	......		Estcourt.
			1847·5	......	......	......		75 37	−01		13·07		Keely.
			1852·5	18 10 w.	0 15 E.	17·55w.		......	......		......		Bayfield.
At sea.....................	41 48	297 38	1841·5	15 54 w.	......	15·9 w.		......	......	......	......		Barnett.
At sea.....................	41 34	304 23	1841·5	18 28 w.	......	18·5 w.		......	......	......	......		Barnett.
At sea.....................	41 50	307 14	1839·5	19 00 w.	......	19·0 w.		......	......	......	......		Bérard.
At sea.....................	42 54	307 37	1841·5	22 22 w.	......	22·4 w.		......	......	......	......		Barnett.
At sea.....................	43 19	313 35	1841·5	24 57 w.	......	25·0 w.		......	......	......	......		Barnett.
At sea.....................	43 34	314 42	1842·5	26 49 w.	......	26·8 w.		74 29	......	74·5	......		Lefroy.
At sea.....................	43 06	315 00	1842·5	26 15 w.	......	26·3 w.		74 12	......	74·2	......		Lefroy.
At sea.....................	43 00	316 10	1841·5	25 43 w.	......	25·7 w.		......	......	......	......		Barnett.
At sea.....................	43 30	317 51	1839·5	23 55 w.	......	23·9 w.		......	......	......	......		Bérard.
At sea.....................	44 33	318 47	1842·5	27 37 w.	......	27·6 w.		74 27	......	74·5	......		Lefroy.
At sea.....................	43 37	319 18	1842·5	28 17 w.	......	28·3 w.		73 53	......	73·9	......		Lefroy.
At sea.....................	42 20	320 16	1842·5	27 07 w.	......	27·1 w.		73 02	......	73·0	......		Lefroy.

ZONE I.—Lat. 40° to 45° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.	Inclination. Observed.	Inclination. Correction to Epoch 1842·5.	Inclination. Corrected.	Force in British units.	Observers.
	° ′	° ′		° ′	° ′	°	° ′	′	°		
At sea	42 59	321 28	1842·5	27 20 w.	......	27·3 w.	73 10	......	73·2	......	Lefroy.
At sea	43 26	322 00	1841·5	28 51 w.	......	28·9 w.	......	......	......	......	Barnett.
At sea	44 14	323 22	1842·5	28 32 w.	......	28·5 w.	73 29	......	73·5	......	Lefroy.
At sea	40 32	323 26	1837·5	24 52 w.	......	24·9 w.	......	......	......	......	Vaillant.
At sea	40 30	323 56	1837·5	25 35 w.	......	25·6 w.	......	......	......	......	Vaillant.
At sea	43 42	324 30	1841·5	27 47 w.	......	27·8 w.	......	......	......	......	Barnett.
At sea	42 03	325 11	1837·5	24 25 w.	......	24·4 w.	......	......	......	......	Vaillant.
At sea	40 37	325 13	1837·5	26 42 w.	......	26·7 w.	......	......	......	......	Vaillant.
At sea	40 09	325 13	1830·5	24 51 w.	......	24·9 w.	69 31	......	69·5	11·16	Erman.
At sea	41 27	327 18	1830·5	25 20 w.	......	25·3 w.	70 11	......	70·2	10·96	Erman.
At sea	42 29	328 33	1830·5	......	......	......	69 47	......	69·8	11·33	Erman.
At sea	43 26	329 27	1830·5	26 38 w.	......	26·6 w.	......	......	......	......	Erman.
At sea	41 22	329 31	1839·5	......	......	......	69 57	......	69·9	......	Sulivan.
At sea	42 39	329 55	1837·5	23 26 w.	......	23·4 w.	......	......	......	......	Vaillant.
At sea	44 24	330 56	1830·5	27 35 w.	......	27·6 w.	71 17	......	71·3	11·30	Erman.
At sea	41 37	331 37	1839·5	22 07 w.	......	22·1 w.	......	......	......	......	Du Petit Thouars.
At sea	43 18	333 04	1837·5	24 22 w.	......	24·4 w.	......	......	......	......	Vaillant.
At sea	44 03	336 25	1837·5	24 20 w.	......	24·3 w.	......	......	......	......	Vaillant.
At sea	40 35	337 15	1836·5	25 00 w.	......	25·0 w.	......	......	......	......	Fitz Roy.
At sea	41 28	338 29	1836·5	25 38 w.	......	25·6 w.	......	......	......	......	Fitz Roy.
At sea	42 06	339 54	1836·5	26 00 w.	......	26·0 w.	......	......	......	......	Fitz Roy.
At sea	43 14	340 17	1839·5	22 52 w.	......	22·9 w.	......	......	......	......	Du Petit Thouars.
At sea	41 08	341 02	1850·5	23 47 w.	......	23·8 w.	......	......	......	......	Collinson.
At sea	44 05	344 05	1839·5	23 09 w.	......	23·2 w.	......	......	......	......	Du Petit Thouars.
At sea	40 15	346 10	1836·5	24 45 w.	......	24·8 w.	......	......	......	......	Fitz Roy.
At sea	41 00	346 30	1836·5	24 49 w.	......	24·8 w.	......	......	......	......	Fitz Roy.
At sea	42 31	347 20	1836·5	24 18 w.	......	24·3 w.	......	......	......	......	Fitz Roy.
At sea	42 37	347 30	1836·5	23 34 w.	......	23·6 w.	......	......	......	......	Fitz Roy.
At sea	43 20	348 00	1836·5	23 50 w.	......	23·8 w.	......	......	......	......	Fitz Roy.
At sea	41 06	348 10	1840·0	......	......	......	......	......	......	9·93	Ross.
At sea	41 44	349 38	1838·0	......	......	......	63 26	......	63·4	......	Stanley.
At sea	40 52	350 45	1838·0	......	......	......	63 50	......	63·8	......	Stanley.
Vigo	42 14	351 15	1858·0	22 34 w.	1 58 w.	24·5 w.	63 35	+42	64·3	10·03	Lamont.
Santiago	42 52	351 31	1858·0	22 35 w.	1 58 w.	24·6 w.	63 58	+42	64·7	10·05	Lamont.
Coimbra	40 12	351 35	1859·5	20 39 w.	3 21 w.	24·0 w.	......	......	......	......	Observatory.
Corunna	43 23	351 37	1858·0	22 42 w.	1 58 w.	24·7 w.	64 09	+42	64·9	10·06	Lamont.
Santander	43 28	356 12	1858·0	20 52 w.	1 58 w.	22·8 w.	63 34	+42	64·3	10·00	Lamont.
Madrid	40 25	356 18	1855·0	......	......	......	61 18	+34	61·9 } 61·8	......	Mahmoud.
			1858·0	20 08 w.	1 58 w.	22·1 w.	61 06	+42	61·8	9·95	Lamont.
Guadalajara	40 37	356 56	1858·0	......	......	......	61 10	+42	61·9	9·75	Lamont.
Bilbao	43 16	357 03	1858·0	20 29 w.	1 58 w.	22·5 w.	63 22	+42	64·1	9·98	Lamont.
Villoria	42 51	357 19	1858·0	20 15 w.	1 58 w.	22·2 w.	62 49	+42	63·5	9·93	Lamont.
Logrono	42 09	357 33	1858·0	......	......	......	62 34	+42	63·3	9·92	Lamont.
St. Sebastian	43 19	357 39	1858·0	20 13 w.	1 58 w.	22·2 w.	63 03	+42	63·8	9·90	Lamont.
Pamplona	42 50	358 18	1858·0	19 57 w.	1 58 w.	21·9 w.	62 40	+42	63·4	9·90	Lamont.
Calatayud	41 24	358 20	1858·0	19 35 w.	1 58 w.	21·6 w.	61 25	+42	62·1	9·74	Lamont.
Abbadia	43 [illegible]	[illegible]	[illegible]	......	......	......	63 06	+36	63·7 } 63·7	......	D'Abbadie.
			[illegible]	[illegible]	3 21 w.	21·6 w.	62 28	+72	63·7	9·84	Perry.
Bayonne	43 [illegible]	[illegible]	[illegible]	[illegible]	1 58 w.	21·9 w. } 21·9 w.	63 07	+42	63·8 } 63·8	9·93 } 9·90	Lamont.
			[illegible]	[illegible]	3 21 w.	21·8 w.	62 30	+72	63·7	9·86	Perry.
Tarragona	41 07	358 45	1858·0	18 21 w.	1 58 w.	20·3 w.	60 38	+42	61·3	9·69	Lamont.
La Teste de Buch	44 38	358 58	1858·0	20 04 w.	1 58 w.	22·0 w.	64 00	+42	64·7	10·01	Lamont.
Saragossa	41 39	359 13	1858·0	19 17 w.	1 58 w.	21·3 w.	61 36	+42	62·3	9·79	Lamont.
Bordeaux	44 50	359 25	1858·0	20 00 w.	1 58 w.	22·0 w. } 21·8 w.	64 06	+42	64·8 } 64·7	10·01 } 9·93	Lamont.
			1869·0	18 13 w.	3 21 w.	21·6 w.	63 23	+72	64·6	9·85	Perry.
Mont de Marsan	43 53	359 30	1858·0	19 40 w.	1 58 w.	21·6 w.	63 19	+42	64·0	9·93	Lamont.
Pau	43 18	359 37	1869·0	17 50 w.	3 21 w.	21·2 w.	61 58	+72	63·2	9·75	Perry.

ZONE II.—LATITUDE 45° TO 50° N.

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ZONE II.—Lat. 45° to 50° N.

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.		Inclination. Observed.	Inclination. Correction to Epoch 1842·5.	Inclination. Corrected.		Force in British units.		Observers.
	° ′	° ′		° ′	° ′	°		° ′	′	°				
Havre	49 29	0 06	1840·0	......	......	......		67 55	−07	67 8		10·38		Gaimard.
Angoulême	45 39	0 09	1858·0	19 50 w.	1 58 w.	21·8 w.		64 39	+42	65·4		10·17		Lamont.
Le Mans	48 00	0 12	1858·0	20 26 w.	1 58 w.	22·4 w.		66 18	+42	67·0		10·27		Lamont.
Poitiers	46 35	0 20	1858·0	19 56 w.	1 58 w.	21·9 w.	21·8 w.	65 08	+42	65·8	65·8	10·16	10·07	Lamont.
			1869·0	18 19 w.	3 21 w.	21·7 w.		64 28	+72	65·7		9·97		Perry.
Tours	47 24	0 41	1858·0	19 54 w.	1 58 w.	21·9 w.		65 44	+42	66·4		10·22		Lamont.
Périgueux	45 11	0 43	1858·0	19 27 w.	1 58 w.	21·4 w.	21·2 w.	......	......	......		......		Lamont.
			1869·0	17 41 w.	3 21 w.	21·0 w.		63 24	+72	64·6		9·89		Perry.
Limoges	45 50	1 15	1858·0	19 24 w.	1 58 w.	21·4 w.		......	......	......		......		Lamont.
Chateauroux	46 48	1 41	1858·0	19 22 w.	1 58 w.	21·3 w.		65 07	+42	65·8		10·16		Lamont.
Orleans	47 54	1 54	1858·0	19 25 w.	1 58 w.	21·4 w.		65 53	+42	66 6		10·23		Lamont.
Etampes	48 26	2 10	1858·0	......	......	......		66 15	+42	67·0		10·28		Lamont.
Amiens	49 54	2 18	1858·0	19 56 w.	1 58 w.	21·9 w.	21·8 w.	......	......	......		......		Lamont.
			1869·0	18 19 w.	3 21 w.	21·7 w.		66 48	+72	68·0		......		Perry.
Paris	48 53	2 20	1827·5	......	......	......	21·2 w.	......	......	......	67·1	10·15	10·13	Sabine.
			1833·5	......	......	......		67 33	−24	67·2		......		Blosseville.
			1834·5	......	......	......		67 21	−22	67·0		......		Duperrey.
			1835·5	22 01 w.	0 53 E.	21·2 w.		67 24	−19	67·1		......		Arago.
			1836·5	......	......	......		67 26	−16	67·2		......		Lottin.
			1837·5	......	......	......		67 21	−14	67·1		......		Bache.
			1838·5	21 38 w.	0 30 E.	21·1 w.		67 15	−11	67·1		......		Darondeau.
			1839·5	......	......	......		67 13	− 8	67·1		10·16		Quetelet.
			1839·5	......	......	......		67 13	− 8	67·1		......		D'Abbadie.
			1842·5	21 29 w.	......	21·5 w.		67 06	......	67·1		10·15		Lamont.
			1869·0	17 51 w.	3 21 w.	21·2 w.		65 53	+72	67·1		10·07		Perry.
Bourges	47 05	2 24	1869·0	17 00 w.	3 21 w.	20·4 w.		64 33	+72	65·8		9·97		Perry.
Fontainebleau	48 24	2 38	1838·5	......	......	......		66 59	−11	66·8		10·03		Fox.
Meaux	48 58	2 53	1858·0	19 16 w.	1 58 w.	21·2 w.		66 24	+42	67·1		10·27		Lamont.
Clermont	45 46	3 00	1838·5	......	......	......		65 12	−10	65·0	65·0	......		Fox.
			1858·0	18 34 w.	1 58 w.	20·5 w.		64 12	+42	64·9		10·09		Lamont.
Nevers	47 00	3 09	1838·5	......	......	......		65 56	−10	65·8		9·94		Fox.
St. Pourcain	46 19	3 17	1838·5	......	......	......		65 33	−10	65·4		......		Fox.
Moulins	46 34	3 20	1838·5	......	......	......	20·3 w.	65 33	−10	65·4	65·4	......	10·02	Fox.
			1858·0	18 39 w.	1 58 w.	20·6 w.		64 43	+42	65·4		10·12		Lamont.
			1869·0	16 30 w.	3 21 w.	19·9 w.		64 05	+72	65·3		9·92		Perry.
Brioude	45 18	3 23	1858·0	18 22 w.	1 58 w.	20·3 w.		63 44	+42	64·4		10·04		Lamont.
Epernay	49 03	3 57	1858·0	......	......	......		66 36	+42	67·3		10·37		Lamont.
Rheims	49 15	4 02	1869·0	16 43 w.	3 21 w.	20·1 w.		65 56	+72	67·1		10·10		Perry.
St. Etienne	45 26	4 23	1869·0	14 55 w.	3 21 w.	18·3 w.		63 04	+72	64·3		9·85		Perry.
Villefranche	45 59	4 42	1869·0	17 00 w.	3 21 w.	20·4 w.		63 30	+72	64·7		9·89		Perry.
Lyons	45 46	4 49	1837·5	......	......	......		64 49	−14	64·6	64·6	9·94	9·91	Bache.
			1859·5	......	......	......		63 53	+48	64·7		......		Fox.
			1869·0	......	......	......		63 16	+72	64·5		9·88		Perry.
Tournon	45 04	4 50	1858·0	17 41 w.	1 58 w.	19·7 w.		63 18	+42	64·0		10·00		Lamont.
Macon	46 18	4 50	1860·5	17 36 w.	2 17 w.	19·9 w.		64 14	+49	65·1		......		Lamont.
Dijon	47 19	5 02	1858·0	17 56 w.	1 58 w.	19·9 w.	20·0 w.	64 55	+42	65·6	65·6	10·09		Lamont.
			1869·0	16 36 w.	3 21 w.	20·0 w.		64 24	+72	65·6		9·94		Perry.
Dôle	47 06	5 29	1869·0	16 05 w.	3 21 w.	19·4 w.		64 13	+72	65·4		9·93		Perry.
Mont Rolland	47 09	5 29	1869·0	......	......	......		64 15	+72	65·5		9·97		Perry.
Grenoble	45 12	5 43	1838·5	......	......	......		64 11	−10	64·0	64·0	......		Fox.
			1869·0	15 48 w.	3 21 w.	19·2 w.		62 54	+72	64·1		9·73		Perry.
Aix	45 44	5 55	1838·5	......	......	......		64 36	−11	64·4		......		Fox.
N. D. de Myans	45 31	5 59	1869·0	15 11 w.	3 21 w.	18·5 w.		62 53	+72	64·1		9·83		Perry.
Geneva	46 12	6 08	1829 0	......	......	......	19·0 w.	......	......	......	64·6	9·93	9·90	Quetelet.
			1834·5	......	......	......		65 05	−27	64·6		9·92		Forbes.
			1837·5	......	......	......		64 50	−14	64·6		......		Bache.
			1838·5	......	......	......		64 55	−11	64·7		9·86		Fox.
			1843·0	18 57 w.	......	19·0 w.		......	......	......		......		Plantamour.
			1859·5	......	......	......		63 53	+48	64·7		......		Fox.
Vesoul	45 37	6 09	1842·5	19 22 w.	......	19·4 w.		......	......	......		......		Lamont.
Annecy	45 54	6 10	1838·5	......	......	......		64 44	−11	64·6		9·81		Fox.
Metz	49 07	6 10	1869·0	15 58 w.	3 21 w.	19·3 w.		65 27	+72	66·7		10·00		Perry.

ZONE II.—Lat. 45° to 50° N. (continued).

Belfort	47 38	6 52	1842·5	19 04 w.	......	19·1 w.	......	......	......		......		Lamont.
Chamouni	45 55	6 52	1832·5	......	......	......	65 00	−27	64·6		......		Forbes.
Payerne	46 48	6 56	1838·5	......	......	......	65 11	−10	65·0		......		Fox.
Le Jardin	45 55	6 59	1832·5	......	......	......	64 58	−27	64·5		......		Forbes.
Sarrebourg	48 44	7 03	1842·5	19 08 w.	......	19·1 w.	......	......	......		......		Lamont.
Bex	46 15	7 03	1832·5	......	......	......	65 00	−27	64·6		......		Forbes.
St. Bernard	45 52	7 10	1832·5	......	......	......	64 55	−27	64·5		......		Forbes.
Neweneck	46 53	7 17	1838·5	......	......	......	65 10	−10	65·0		......		Fox.
Isenheim	48 01	7 17	1869·0	15 47 w.	3 21 w.	19·1 w.	64 36	+72	65·8		9·96		Perry.
Aosta	45 44	7 20	1832·5	......	......	......	64 47	−26	64·3		......		Forbes.
Homburg	49 19	7 21	1842·5	19 03 w.	......	19·1 w.	66 49	......	66·8		10·17		Lamont.
Berne	46 57	7 25	1838·5	......	......	......	65 10	−10	65·0		9·87		Fox.
Basle	47 33	7 33	1838·5	......	......	......	65 35	−10	65·4		9·95		Fox.
Oettingen	47 33	7 36	1842·5	18 38 w.	......	18·6 w.	65 23	......	65·4		10·05		Lamont.
Pirmasenz	49 12	7 37	1842·5	18 53 w.	......	18·9 w.	66 49	......	66·8		10·19		Lamont.
Turin	45 05	7 42	1838·5	......	......	......	63 52	−11	63·7		9·85		Bache.
			1839·5	......	......	......	63 56	−08	63·8	63·7	9·90	9·88	Quetelet.
			1867·5	......	......	......	62 26	+67	63·6		......		L. F. Kämtz.
Kaiserslautern	49 28	7 45	1842·5	18 50 w.	......	18·8 w.	66 52	......	66·9		10·18		Lamont.
Strasburg	48 35	7 45	1860·0	15 35 w.	3 21 w.	18·9 w.	64 40	+72	65·9		9·94		Perry.
[illegible]	[illegible]	7 47	1838·5	......	......	......	66 06	−11	65·9		10·00		Forbes.
[illegible]	[illegible]	7 49	1842·5	18 46 w.	......	18·8 w.	66 08	......	66·1		10·10		Lamont.
Freiburg	48 10	7 51	1842·5	18 32 w.	......	18·5 w.	65 48	......	65·8		10·11		Lamont.
Interlachen	46 42	7 52	1832·5	......	......	......	65 23	−27	64·9		......		Fox.
			1832·5	......	......	......	65 23	−27	64·9	64·9	......		Forbes.
Offenburg	48 28	7 56	1842·5	18 37 w.	......	18·6 w.	66 03	......	66·1		10·09		Lamont.
Neustadt	49 22	8 08	1842·5	18 40 w.	......	18·7 w.	66 47	......	66·8		10·16		Lamont.
Langenkandel	49 05	8 12	1842·5	18 39 w.	......	18·7 w.	66 29	......	66·5		10·15		Lamont.
Baden	48 45	8 17	1838·5	......	......	......	66 20	−11	66·2		......		Fox.
Lucerne	47 03	8 19	1859·5	......	......	......	64 08	+48	64·9		......		Fox.
Carlsruhe	49 01	8 24	1842·5	18 21 w.	......	18·4 w.	66 28	......	66·5		10·14		Lamont.
Ludwigshafen	49 29	8 26	1842·5	18 27 w.	......	18·5 w.	66 55	......	66·9		10·21		Lamont.
Speyer	49 18	8 26	1842·5	18 29 w.	......	18·5 w.	66 41	......	66·7		10·17		Lamont.
Mannheim	49 29	8 27	1838·5	......	......	......	66 49	−11	66·6	66·7	10·02	10·10	Fox.
			1842·5	18 25 w.	......	18·4 w.	66 50	......	66·8		10·17		Lamont.
Durlach	49 00	8 28	1842·5	18 22 w.	......	18·4 w.	66 27	......	66·5		10·14		Lamont.
Donaueschingen	47 57	8 28	1842·5	18 15 w.	......	18·3 w.	65 38	......	65·6		10·06		Lamont.
Isola Bella	45 53	8 32	1850·0	17 27 w.	0 55 w.	18·4 w.	63 45	+20	64·1		9·81		Kreil.
St. Gothard	46 32	8 33	1832·5	......	......	......	65 10	−26	64·7		9·91		Forbes.
Zurich	47 23	8 33	1867·5	......	......	......	64 00	+67	65·1		......		L. F. Kämtz.
Oberndorf	48 17	8 34	1842·5	16 31 w.	......	16·5 w.	65 15	......	65·3		10·01		Lamont.
Schaffhausen	47 42	8 38	1859·5	......	......	......	64 33	+48	65·4		......		Fox.
Darmstadt	49 52	8 39	1842·5	18 03 w.	......	18·1 w.	67 19	......	67·3		10·10		Lamont.
Pforzheim	48 54	8 41	1842·5	18 23 w.	......	18·4 w.	66 29	......	66·5		10·18		Lamont.
Heidelberg	48 39	8 41	1842·5	18 20 w.	......	18·3 w.	66 40	......	66·7		10·11		Lamont.
Stockach	47 51	8 59	1842·5	18 06 w.	......	18·1 w.	65 35	......	65·6		10·07		Lamont.
Tubingen	48 31	9 03	1842·5	18 09 w.	......	18·2 w.	......	......	......		......		Lamont.
Como	45 48	9 04	1850·0	16 47 w.	0 55 w.	17·7 w.	63 40	+20	64·0	63·9	9·83		Kreil.
			1867·5	......	......	......	62 42	+67	63·8		......		L. F. Kämtz.
Pavia	45 11	9 10	1850·0	17 07 w.	0 55 w.	18·0 w.	63 08	+29	63·5		9·81		Kreil.
			1867·5	......	......	......	62 12	+67	63·3	63·4	......		L. F. Kämtz.
Milan	45 28	9 11	1838·5	......	......	......	63 55	−11	63·7		......		Bache.
			1839·5	......	......	......	64 16	−08	64·1		......		Quetelet.
			1850·0	17 13 w.	0 55 w.	18·1 w.	63 08	+20	63·5	63·7	......		Kreil.
			1867·5	......	......	......	62 27	+67	63·6		......		L. F. Kämtz.
Heilsbronn	49 09	9 13	1842·5	17 19 w.	......	17·3 w.	......	......	......		......		Lamont.
Mittenberg	49 42	9 15	1842·5	18 22 w.	......	18·4 w.	66 50	......	66·8		10·14		Lamont.
Meersburg	47 41	9 17	1842·5	17 55 w.	......	17·9 w.	65 24	......	65·4		10·00		Lamont.
Bregenz	47 30	9 41	1850·0	16 27 w.	0 55 w.	17·4 w.	64 49	+20	65·2		9·93		Kreil.

ZONE II.—Lat. 45° to 50° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.	Inclination. Observed.	Inclination. Correction to Epoch 1842·5.	Inclination. Corrected.	Force in British units.	Observers.
	° ′	° ′		° ′	° ′	°	° ′	′	°		
Bludenz	47 0[illegible]	9 19	1850·0	16 28 w.	0 55 w.	17·4 w.	64 30	+20	64·8	9·[illegible]0	Kreil.
Sondrio	46 10	9 53	1850·0	16 09 w.	0 55 w.	17·1 w.	63 50	+20	64·2	9·83	Kreil.
Wurzburg	49 47	9 55	1842·5	17 51 w.	......	17·9 w.	66 39	......	66·7	10·11	Lamont.
Arnstein	49 58	9 57	1842·5	17 48 w.	......	17·8 w.	66 49	......	66·8	10·16	Lamont.
Weiler	47 35	9 57	1842·5	17 30 w.	......	17·5 w.	65 14	......	65·2	10·05	Lamont.
Ulm	48 25	10 00	1842·5	17 35 w.	......	17·6 w.	65 43	......	65·7	10·07	Lamont.
Crailsheim	49 08	10 04	1842·5	17 38 w.	......	17·6 w.	......	......	......	.....	Lamont.
Aalen	48 50	10 05	1842·5	......	......	......	65 59	......	66·0	10·01	Lamont.
Ellwangen	48 58	10 08	1842·5	17 41 w.	......	17·7 w.	65 58	......	66·0	10·02	Lamont.
Heidenheim	48 41	10 09	1842·5	17 41 w.	......	17·7 w.	......	......	......	......	Lamont.
Rothenburg	49 23	10 11	1842·5	17 38 w.	......	17·6 w.	66 22	......	66·4	10·09	Lamont.
Memmingen	48 00	10 11	1842·5	17 28 w.	......	17·5 w.	65 23	......	65·4	10·03	Lamont.
Brescia	45 32	10 11	1850·0	16 22 w.	0 55 w.	17·3 w.	63 10	+20	63·5	9·81	Kreil.
St. Christopher	47 08	10 12	1850·0	......	......	......	64 16	+20	64·6	9·82	Kreil.
Uffenheim	49 33	10 13	1842·5	17 41 w.	......	17·7 w.	66 26	......	66·4	10·07	Lamont.
Immenstadt	47 33	10 13	1842·5	17 26 w.	......	17·4 w.	65 06	......	65 1	10 01	Lamont.
Gunzberg	48 27	10 15	1842·5	17 26 w.	......	17·4 w.	65 43	......	65·7	10·06	Lamont.
Kempten	47 43	10 18	1842·5	17 22 w.	......	17·4 w.	65 12	......	65·2	10·01	Lamont.
Dinkelsbuhl	49 04	10 19	1842·5	17 31 w.	......	17·5 w.	66 08	......	66·1	10·07	Lamont.
Bormio	46 30	10 22	1850·0	16 17 w.	0 55 w.	17·2 w.	63 56	+20	64·3	9·82	Kreil.
Burgau	48 26	10 24	1842·5	17 23 w.	......	17·4 w.	65 44	......	65·7	10·07	Lamont.
St. Maria	46 31	10 24	1850·0	16 09 w.	0 55 w.	17·1 w.	63 57	+20	64·3	9·85	Kreil.
Sailing	47 32	10 25	1842·5	17 08 w.	......	17·1 w.	65 00	......	65·0	10·00	Lamont.
Lauingen	48 34	10 25	1842·5	17 29 w.	......	17·5 w.	......	......	......	......	Lamont.
Stilfersjoch	46 32	10 26	1850·0	......	......	......	63 58	+20	64·3	......	Kreil.
Nordlingen	48 51	10 29	1842·5	17 25 w.	......	17·4 w.	......	......	......	......	Lamont.
Mindelheim	48 03	10 29	1842·5	17 20 w.	......	17·3 w.	65 21	......	65·3	10·02	Lamont.
Dillengen	48 35	10 30	1842·5	17 21 w.	......	17·3 w.	65 46	......	65·8	10·05	Lamont.
Mals	46 41	10 30	1850·0	16 05 w.	0 55 w.	17·0 w.	64 01	+20	64 3	9·85	Kreil.
Landeck	47 08	10 31	1850·0	16 10 w.	0 55 w.	17·1 w.	64 22	+20	64·7	9·90	Kreil.
[illegible]	49 18	10 34	1842·5	......	......	......	66 19	......	66·3	10·11	Lamont.
Oettingen	48 57	10 36	1842·5	17 21 w.	......	17·3 w.	65 59	......	66·0	10 05	Lamont.
Kaufbeuren	47 53	10 37	1842·5	17 21 w.	......	17·3 w.	65 09	......	65·1	9·97	Lamont.
Imst	47 14	10 40	1850·0	16 08 w.	0 55 w.	17·1 w.	64 23	+20	64·7	9·84	Kreil.
Fussen	47 34	10 42	1842·5	17 09 w.	......	17·1 w.	65 00	......	65 0	9·81	Lamont.
Wemding	48 53	10 43	1842·5	17 28 w.	......	17·5 w.	......	......	......	......	Lamont.
Gunzenhausen	49 07	10 45	1842·5	17 22 w.	......	17·4 w.	66 07	......	66·1	10·08	Lamont.
Donauwörth	48 43	10 47	1842·5	17 14 w.	......	17·2 w.	65 53	......	65·9	10 07	Lamont.
Mantua	45 09	10 47	1850·0	15 43 w.	0 55 w.	16·6 w.	62 55	+20	63·3	9·82	Kreil.
Buchdorf	48 47	10 49	1842·5	17 13 w.	......	17·2 w.	......	......	......	......	Lamont.
Riva	45 53	10 50	1850·0	......	......	......	63 16	+20	63·6	9·82	Kreil.
Berolsheim	49 01	10 51	1842·5	18 04 w.	......	18·1 w.	......	......	......	......	Lamont.
Landsberg	48 03	10 53	1842·5	17 08 w.	......	17·1 w.	65 21	......	65·3	10·02	Lamont.
Bamberg	49 53	10 53	1842·5	17 16 w.	......	17·3 w.	66 40	......	66·7	9·86	Lamont.
Pfaffenhofen	48 33	10 54	1842·5	16 55 w.	......	16·9 w.	65 39	......	65·7	10·05	Lamont.
Augsburg	48 22	10 54	1842·5	17 09 w.	......	17·1 w.	65 35	......	65·6	10·04	Lamont.
Peitting	47 48	10 55	1842·5	17 08 w.	......	17·1 w.	......	......	......	......	Lamont.
Verona	45 26	10 58	1850·0	15 39 w.	0 55 w.	16·6 w.	63 06	+20	63·4	9·85	Kreil.
Furth	49 29	10 59	1842·5	17 12 w.	......	17·2 w.	......	......	......	......	Lamont.
Erlangen	49 36	11 00	1842·5	17 17 w.	......	17·3 w.	66 23	......	66·4	10·11	Lamont.
Schwabach	49 20	11 01	1842·5	17 14 w.	......	17·2 w.	66 05	......	66·1	10·04	Lamont.
Hohenpreissenburg	47 48	11 01	1842·5	17 02 w.	......	17·0 w.	65 08	......	65·1	10·01	Lamont.
Forchheim	49 43	11 03	1842·5	17 16 w.	......	17·3 w.	......	......	......	......	Lamont.
Hornle	47 39	11 03	1842·5	16 59 w.	......	17·0 w.	64 56	......	64·9	......	Lamont.
Kohlgrub	47 40	11 03	1842·5	17 00 w.	......	17·0 w.	64 55	......	64·9	9·95	Lamont.
Monheim	48 51	11 04	1842·5	......	......	......	66 01	......	66·0	10·08	Lamont.
Nuremberg	49 27	11 04	1842·5	17 13 w.	......	17·2 w.	66 15	......	66·3	......	Lamont.
Partenkirchen	47 30	11 06	1842·5	16 56 w.	......	16·9 w.	64 50	......	64·8	9·95	Lamont.
Trient	46 04	11 06	1837·5	......	......	......	64 05	−13	63·9 } 63·7	9·88 } 9·83	Forbes.
			1850·0	15 57 w.	0 55 w.	16·9 w.	63 18	+20	63·6	9·78	Kreil.
Abensberg	48 49	11 07	1842·5	16 47 w.	......	16·8 w.	65 52	......	65·9	10·09	Lamont.
Meran	46 40	11 08	1850·0	16 07 w.	0 55 w.	17·0 w.	63 54	+20	64·2	9·84	Kreil.

ZONE II.—Lat. 45° to 50° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.	Inclination. Observed.	Inclination. Correction to Epoch 1842·5.	Inclination. Corrected.		Force in British units.		Observers.
	° ′	° ′		° ′	° ′	°	° ′	′	°				
Weilheim	47 50	11 09	1842·5	17 01 w.	......	17·0 w.	65 10	......	65·2		10·01		Lamont.
Neuburg, D.	48 45	11 11	1842·5	17 07 w.	......	17·1 w.	65 47	......	65·8		10·05		Lamont.
Murnau	47 41	11 16	1842·5	16 55 w.	......	16·9 w.	64 58	......	65·0		9·87		Lamont.
Lauf	49 31	11 17	1842·5	17 10 w.	......	17·2 w.	66 15	......	66·3		10·08		Lamont.
Botzen	46 30	11 18	1850·0	16 03 w.	0 55 w.	17·0 w.	63 52	+20	64·2		9·88		Kreil.
Altdorf	49 25	11 21	1842·5	17 03 w.	......	17·1 w.	......	......	......		......		Lamont.
Kochel	47 39	11 22	1842·5	16 50 w.	......	16·8 w.	65 01	......	65·0		10·00		Lamont.
Innspruck	47 16	11 24	1834·5	......	......	......	65 01	−22	64·6	° 64·6	......	9·88	Listing.
			1837·5	......	......	......	64 49	−13	64·6		9·90		Forbes.
			1839·5	......	......	......	64 44	−08	64·6		9·90		Quetelet.
			1850·0	15 51 w.	0 55 w.	16·8 w.	64 15	+20	64·6		9·85		Kreil.
Benedictbeurn	47 43	11 24	1842·5	16 51 w.	......	16·9 w.	65 05	......	65·1		10·01		Lamont.
Hersbruck	49 31	11 25	1842·5	17 05 w.	......	17·1 w.	66 19	......	66·3		10·10		Lamont.
Brenner	47 00	11 25	1850·0	15 50 w.	0 55 w.	16·7 w.	63 58	+20	64·3		9·83		Kreil.
Ingoldstadt	48 46	11 25	1842·5	16 53 w.	......	16·9 w.	65 58	......	66·0		10·04		Lamont.
Wolfrathshausen	47 55	11 25	1842·5	16 50 w.	......	16·8 w.	65 12	......	65·2		10·01		Lamont.
Benedictenwand	47 39	11 27	1842·5	16 47 w.	......	16·8 w.	64 59	......	65·0		9·99		Lamont.
Greding	49 03	11 27	1842·5	16 59 w.	......	17·0 w.	66 03	......	66·1		10·09		Lamont.
Neumarkt	49 16	11 29	1842·5	16 59 w.	......	17·0 w.	66 10	......	66·2		10·11		Lamont.
Tann	49 10	11 31	1842·5	17 49 w.	......	17·8 w.	......	......	......		......		Lamont.
Tolz	47 46	11 33	1842·5	16 39 w.	......	16·7 w.	64 58	......	65·0		9·95		Lamont.
Vicenza	45 32	11 33	1850·0	15 38 w.	0 55 w.	16·5 w.	63 02	+20	63·4		9·86		Kreil.
Bayreuth	49 57	11 35	1842·5	17 11 w.	......	17·2 w.	66 32	......	66·5		10·09		Lamont.
Geisenfeld	48 41	11 36	1842·5	16 52 w.	......	16·9 w.	......	......	......		......		Lamont.
Munich	48 09	11 36	1842·5	16 47 w.	......	16·8 w.	65 19	......	65·3		10·01		Lamont.
Rattenberg	47 27	11 37	1850·0	15 36 w.	0 55 w.	16·5 w.	64 23	+20	64·7		9·90		Kreil.
Holzkirchen	47 52	11 42	1842·5	16 43 w.	......	16·7 w.	65 08	......	65·1		9·98		Lamont.
Sulzbach	49 30	11 44	1842·5	16 54 w.	......	16·9 w.	66 22	......	66·4		10·14		Lamont.
Freysing	48 24	11 45	1842·5	16 41 w.	......	16·7 w.	65 29	......	65·5		10·02		Lamont.
Rovigo	45 04	11 46	1850·0	15 02 w.	0 55 w.	15·9 w.	62 39	+20	63·0		9·86		Kreil.
Miesbach	47 47	11 51	1842·5	16 31 w.	......	16·5 w.	65 02	......	65·0		9·99		Lamont.
Schliersee	47 44	11 52	1842·5	16 31 w.	......	16·5 w.	64 54	......	64·9		9·96		Lamont.
Amberg	49 27	11 52	1842·5	16 52 w.	......	16·9 w.	66 13	......	66·2		10·09		Lamont.
Padua	45 24	11 52	1850·0	15 10 w.	0 55 w.	16·1 w.	62 53	+20	63·2		9·87		Kreil.
Kelheim	48 55	11 52	1842·5	16 43 w.	......	16·7 w.	65 47	......	65·8		10·05		Lamont.
Brunnecken	46 48	11 54	1850·0	15 42 w.	0 55 w.	16·6 w.	63 51	+20	64·2		9·85		Kreil.
Erding	48 18	11 55	1842·5	16 41 w.	......	16·7 w.	65 22	......	65·4		10·02		Lamont.
Moosburg	48 28	11 56	1842·5	16 40 w.	......	16·7 w.	......	......	......		......		Lamont.
Osterhofen	47 41	12 00	1842·5	16 38 w.	......	16·6 w.	64 52	......	64·9		9·96		Lamont.
Aibling	47 52	12 00	1842·5	16 28 w.	......	16·5 w.	65 03	......	65·1		9·90		Lamont.
Wendelstein	47 42	12 01	1842·5	......	......	......	64 53	......	64·9		9·96		Lamont.
Agordo	46 17	12 03	1850·0	15 39 w.	0 55 w.	16·6 w.	63 28	+20	63·8		9·89		Kreil.
Schwandorf	49 20	12 07	1842·5	16 41 w.	......	16·7 w.	66 06	......	66·1		10·08		Lamont.
Roth	47 59	12 07	1842·5	......	......	......	66 15	......	66·3		10·13		Lamont.
Landshut	48 32	12 08	1842·5	16 36 w.	......	16·6 w.	65 32	......	65·5		10·03		Lamont.
Rosenheim	47 52	12 08	1842·5	16 24 w.	......	16·4 w.	......	......	......		10·00		Lamont.
Weiden	49 41	12 09	1842·5	......	......	......	65 25	......	65·4		9·74		Lamont.
Haag	48 10	12 10	1842·5	16 29 w.	......	16·5 w.	65 15	......	65·3		9·99		Lamont.
Nabburg	49 27	12 10	1842·5	16 54 w.	......	16·9 w.	66 14	......	66·2		10·11		Lamont.
Belluno	46 08	12 13	1850·0	14 35 w.	0 55 w.	15·5 w.	63 19	+20	63·7		9·89		Kreil.
Mitterteich	49 57	12 14	1842·5	16 45 w.	......	16·7 w.	......	......	......		......		Lamont.
Wasserburg	48 03	12 14	1842·5	16 31 w.	......	16·5 w.	65 08	......	65·1		9·97		Lamont.
Velden	48 22	12 15	1842·5	16 29 w.	......	16·5 w.	65 24	......	65·4		10·02		Lamont.
Giesenhausen	48 28	12 16	1842·5	16 32 w.	......	16·5 w.	......	......	......		......		Lamont.
Conegliano	45 53	12 18	1850·0	15 15 w.	0 55 w.	16·2 w.	63 06	+20	63·4		9·87		Kreil.
Venice	45 26	12 20	1838·5	......	......	......	63 22	−11	63·2	63·1	9·86	9·85	Bache.
			1839·5	......	......	......	63 06	−08	63·0		9·84		Quetelet.
			1850·0	15 04 w.	0 55 w.	16·0 w.	62 48	+20	63·1		9·85		Kreil.
			1867·5	......	......	......	62 04	+67	63·2		......		L. F. Kämtz.
St. Johann	47 32	12 20	1850·0	15 15 w.	0 55 w.	16·2 w.	64 24	+20	64·7		9·90		Kreil.
Vilsbiburg	48 27	12 21	1842·5	16 28 w.	......	16·5 w.	......	......	......		......		Lamont.

ZONE II.—Lat. 45° to 50° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.		Inclination. Observed.	Inclination. Correction to Epoch 1842·5.	Inclination. Corrected.		Force in British units.		Observers.
	° ′	° ′		° ′	° ′	°		° ′	′	°				
Muhldorf	48 14	12 32	1842·5	16 23 w.	......	16·4 w.		65 15	......	65·3		9·98		Lamont.
Straubing	48 52	12 34	1842·5	16 24 w.	......	16·4 w.		65 43	......	65·7		10·05		Lamont.
Hochberg	47 50	12 39	1842·5	16 12 w.	......	16·2 w.		65 02	......	65·0		9·99		Lamont.
Stallwang	49 03	12 40	1842·5	16 24 w.	......	16·4 w.		65 48	......	65·8		10·03		Lamont.
Cham	49 13	12 40	1842·5	16 24 w.	......	16·4 w.		65 59	......	66·0		10·07		Lamont.
Altotting	48 14	12 40	1842·5	16 41 w.	......	16·7 w.		65 10	......	65·2		9·98		Lamont.
Plan	49 52	12 41	1850·0	15 33 w.	0 55 w.	16·5 w.		65 54	+20	66·2		10·08		Kreil.
Lienz	46 50	12 44	1850·0	15 20 w.	0 55 w.	16·2 w.		63 49	+20	64·1		9·88		Kreil.
Tittmoning	48 04	12 45	1842·5	16 13 w.	......	16·2 w.		65 07	......	65·1		10·18		Lamont.
Eggenfelden	48 24	12 47	1842·5	16 16 w.	......	16·3 w.		65 15	......	65·3		9·97		Lamont.
Burghausen	48 09	12 50	1842·5	16 11 w.	......	16·2 w.		65 09	......	65·2		9·98		Lamont.
Reichenhall	47 43	12 53	1842·5	16 06 w.	......	16·1 w.		64 56	......	64·9		9·73		Lamont.
Viechtach	49 05	12 53	1842·5	......	......	......		65 45	......	65·8		10·02		Lamont.
Deggendorff	48 50	12 58	1842·5	16 11 w.	......	16·2 w.		65 40	......	65·7		10·11		Lamont.
Laufen	47 57	12 59	1842·5	16 11 w.	......	16·2 w.		65 03	......	65 1		9·98		Lamont.
Berchtesgaden	47 38	13 00	1842·5	......	......	......		64 43	......	64·7		9·97		Lamont.
Salzburg	47 48	13 02	1837·5	......	......	......	° 16·2 w.	65 04	−13	64·9	° 64·9	9·96	9·96	Forbes.
			1842·5	16 12 w.	......	16·2 w.		64 58	......	65·0		9·99		Lamont.
			1850·0	15 17 w.	0 55 w.	16·2 w.		64 36	+20	64·9		9·94		Kreil.
Bockstein	47 00	13 02	1850·0	......	......	......		63 46	+20	64·1		9·83		Kreil.
Gastein	47 10	13 05	1850·0	14 58 w.	0 55 w.	15·9 w.		63 59	+20	64·3		9·93		Kreil.
Gaisberg	47 47	13 07	1842·5	16 05 w.	......	16·1 w.		64 52	......	64·9		9·95		Lamont.
Golling	47 35	13 08	1850·0	15 00 w.	0 55 w.	15·9 w.		64 25	+20	64·8		9·93		Kreil.
Regen	48 57	13 08	1842·5	16 11 w.	......	16·2 w.		65 44	......	65·7		10·04		Lamont.
Altheim	48 15	13 11	1842·5	16 34 w.	......	16·6 w.		......	......	......		......		Lamont.
Udine	46 04	13 15	1850·0	......	......	......		63 06	+20	63·4		9·87		Kreil.
Schomberg	48 51	13 20	1842·5	16 03 w.	......	16·1 w.		65 27	......	65·5		10·02		Lamont.
Klattau	49 24	13 22	1850·0	15 23 w.	0 55 w.	16·3 w.		65 14	+20	65·6		9·87		Kreil.
Pilsen	49 55	13 23	1850·0	......	......	......		65 33	+20	65·9		9·94		Kreil.
Grafenau	48 52	13 23	1842·5	16 07 w.	......	16·1 w.		......	......	......		......		Lamont.
Scherding	48 27	13 24	1850·0	14 52 w.	0 55 w.	15·8 w.		64 44	+20	65·1		9·88		Kreil.
Passau	48 34	13 28	1842·5	16 01 w.	......	16·0 w.		65 26	......	65·4		......		Lamont.
Radstadt	47 23	13 28	1850·0	14 52 w.	0 55 w.	15·8 w.		64 11	+20	64·5		9·95		Kreil.
Gmund	46 54	13 30	1850·0	15 06 w.	0 55 w.	16·0 w.		63 43	+20	64·1		9·87		Kreil.
St. George	47 55	13 31	1850·0	15 07 w.	0 55 w.	16·0 w.		64 40	+20	65·0		9·97		Kreil.
Ischl	47 43	13 34	1850·0	15 00 w.	0 55 w.	15·9 w.		64 22	+20	64·7		9·86		Kreil.
Vocklabruck	48 01	13 36	1850·0	14 42 w.	0 55 w.	15·6 w.		64 38	+20	64·0		9·94		Kreil.
Parenzo	45 14	13 36	1850·0	14 46 w.	0 55 w.	15·7 w.		......	......	......		......		Kreil.
Gorz	45 56	13 38	1850·0	13 59 w.	0 55 w.	14·9 w.		62 57	+20	63·3		9·86		Kreil.
Bleiberg	46 36	13 42	1850·0	14 38 w.	0 55 w.	15·6 w.		63 25	+20	63·7		9 90		Kreil.
Rachel	48 59	13 43	1842·5	15 52 w.	......	15·9 w.		65 43	......	65·7		10·04		Lamont.
Trieste	45 39	13 45	1838·5	......	......	......	15·6 w.	63 21	−11	63·2	63·1	9·88	9·86	Bache.
			1850·0	14 32 w.	0 55 w.	15·5 w.		62 44	+20	63·1		9·85		Kreil.
			1858·5	13 44 w.	1 55 w.	15·7 w.		62 19	+43	63·0		......		Novara.
			1867·5	......	......	......		61 56	+67	63·1		......		L. F. Kämtz.
Kremsmunster	48 03	14 08	1850·0	14 32 w.	0 55 w.	15·5 w.	15·6 w.	64 42	+20	65·0	65·0	9·94	9·90	Kreil.
			1853·5	14 17 w.	1 20 w.	15·6 w.		64 25	+30	64·9		9·87		Reslhuber.
			1867·5	......	......	......		63 55	+67	65·0		......		L. F. Kämtz.
Pisek	49 19	14 09	1850·0	14 53 w.	0 55 w.	15·8 w.		65 09	+20	65·5		9·89		Kreil.
Adelsberg	45 46	14 14	1850·0	13 50 w.	0 55 w.	14·7 w.		62 46	+20	63·1		9·85		Kreil.
Lietzen	47 34	14 15	1850·0	14 35 w.	0 55 w.	15·5 w.		64 10	+20	64·5		9·94		Kreil.
Linz	48 18	14 16	1837·5	......	......	......		65 15	−13	65·0	65·0	10·01	9·98	Forbes.
			1850·0	14 39 w.	0 55 w.	15·6 w.		64 42	+20	65·0		9·95		Kreil.
Klagenfurt	46 37	14 18	1850·0	14 28 w.	0 55 w.	15·4 w.		63 27	+20	63·8		9·92		Kreil.
St. Lambrecht	47 04	14 18	1850·0	14 33 w.	0 55 w.	15·5 w.		63 49	+20	64·1		9·93		Kreil.
Fiume	45 19	14 27	1850·0	14 21 w.	0 55 w.	15·3 w.		62 25	+20	62·7		9·83		Kreil.
Admont	47 35	14 28	1850·0	14 13 w.	0 55 w.	15·1 w.		64 00	+20	64·3		9·92		Kreil.
Budweis	49 00	14 28	1850·0	......	......	......		65 04	+20	65·4		9·98		Kreil.
Laibach	46 03	14 30	1837·5	......	......	......		63 24	−13	63·2		9·85	9·85	Forbes.
			1850·0	13 59 w.	0 55 w.	14·9 w.		62 54	+20	63·2		9·86		Kreil.
Steinberg	48 35	14 40	1850·0	......	......	......		64 51	+20	65·2		9·93		Kreil.
Silberberg	48 38	14 43	1850·0	......	......	......		64 45	+20	65·1		9·89		Kreil.

ZONE II.—Lat. 45° to 50° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.	Inclination. Observed.	Inclination. Correction to Epoch 1842·5.	Inclination. Corrected.	Force in British units.	Observers.
	° ′	° ′		° ′	° ′	°	° ′	′	°		
Kallevang	47 27	14 45	1850·0	14 09 w.	0 55 w.	15·1 w.	63 49	+20	64·1	9·89	Kreil.
Gratzen	48 48	14 47	1850·0	14 22 w.	0 55 w.	15·3 w.	64 55	+20	65·3	9·89	Kreil.
Eisenerz	47 32	14 53	1850·0	14 09 w.	0 55 w.	15·1 w.	63 55	+20	64·3	9·91	Kreil.
St. Paul	46 43	14 54	1850·0	13 56 w.	0 55 w.	14·9 w.	63 21	+20	63·7	9·91	Kreil.
Neuhaus	49 08	14 59	1850·0	14 26 w.	0 55 w.	15·4 w.	65 06	+20	65·4	9·93	Kreil.
Neustadtl	45 48	15 12	1850·0	13 19 w.	0 55 w.	14·2 w.	62 39	+20	63·0	9·92	Kreil.
Aflenz	47 32	15 14	1850·0	13 52 w.	0 55 w.	14·8 w.	63 54	+20	64·2	......	Kreil.
Bruck	47 25	15 17	1850·0	13 52 w.	0 55 w.	14·8 w.	63 51	+20	64·2	9·92	Kreil.
Seelau	49 32	15 17	1850·0	14 12 w.	0 55 w.	15·1 w.	65 24	+20	65·7	9·96	Kreil.
Cilli	46 14	15 18	1850·0	13 41 w.	0 55 w.	14·6 w.	62 53	+20	63·2	9·89	Kreil.
Melk	48 14	15 21	1850·0	13 57 w.	0 55 w.	14·9 w.	64 35	+20	64·9	9·96	Kreil.
Caslau	49 57	15 22	1850·0	14 05 w.	0 55 w.	15·0 w.	65 31	+20	65·9	9·97	Kreil.
Gratz	47 04	15 28	1850·0	13 49 w.	0 55 w.	14·7 w.	63 30	+20	63·8	......	Kreil.
Carlstadt	45 29	15 35	1850·0	13 48 w.	0 55 w.	14·7 w.	62 24	+20	62·7	9·83	Kreil.
Iglau	49 25	15 38	1850·0	13 56 w.	0 55 w.	14·9 w.	65 17	+20	65·6	10·02	Kreil.
Horn	48 40	15 39	1850·0	13 40 w.	0 55 w.	14·6 w.	64 42	+20	65·0	9·95	Kreil.
Marburg	46 35	15 41	1850·0	13 28 w.	0 55 w.	14·4 w.	63 13	+20	63·5	9·89	Kreil.
Schottwein	47 39	15 52	1850·0	13 53 w.	0 55 w.	14·8 w.	63 55	+20	64·3	9·91	Kreil.
Gleichenberg	46 52	15 57	1850·0	13 21 w.	0 55 w.	14·3 w.	63 28	+20	63·8	9·93	Kreil.
Agram	45 49	15 59	1850·0	13 37 w.	0 55 w.	14·5 w.	62 30	+20	62·8	9·84	Kreil.
Znaim	48 51	16 05	1850·0	13 35 w.	0 55 w.	14·5 w.	64 48	+20	65·1	10·00	Kreil.
Steinamanger	47 12	16 16	1850·0	......	......	......	63 51	+20	64·2	10·01	Kreil.
Petrina	45 26	16 18	1850·0	13 26 w.	0 55 w.	14·4 w.	62 17	+20	62·6	9·81	Kreil.
Warasdin	46 08	16 18	1850·0	......	......	......	62 49	+20	63·1	9·88	Kreil.
Leitomischl	49 53	16 19	1850·0	13 34 w.	0 55 w.	14·5 w.	65 31	+20	65·9	10·01	Kreil.
Vienna	48 15	16 22	1842·5	14 27 w.	......	14·5 w. } 14·5 w.	64 42	......	64·7 } 64·7	......	Lamont.
			1850·0	13 31 w.	0 55 w.	14·4 w.	64 17	+20	64·6	9·91	Kreil.
Odenburg	47 41	16 35	1850·0	13 23 w.	0 55 w.	14·3 w.	64 02	+20	64·4	9·98	Kreil.
Brunn	49 11	16 37	1850·0	13 48 w.	0 55 w.	14·7 w.	65 15	+20	65·6	9·98	Kreil.
Bellovar	45 53	16 52	1850·0	[illegible]	0 55 w.	14·1 w.	62 36	+20	62·9	9·87	Kreil.
Lundenburg	48 45	16 54	[illegible]	[illegible]	[illegible]	14·1 w.	64 43	+20	65·1	10·02	Kreil.
Pressburg	48 09	17 06	[illegible]	[illegible]	[illegible]	14 3 w.	64 00	+20	64·3	9·94	Kreil.
Olmutz	49 36	17 15	1850·0	13 06 w.	0 55 w.	14·0 w.	65 19	+20	65·7	10·04	Kreil.
Neu Gradisca	45 14	17 26	1850·0	12 55 w.	0 55 w.	13·8 w.	61 56	+20	62·3	9·80	Kreil.
Troppau	49 56	17 53	1850·0	12 46 w.	0 55 w.	13·7 w.	65 21	+20	65·7	10 06	Kreil.
Trentschin	48 52	18 03	1850·0	....	......	......	64 49	+20	65·1	10·08	Kreil.
Kenese	47 02	18 08	1850·0	12 40 w.	0 55 w.	13·6 w.	63 24	+20	63·7	9·96	Kreil.
Komorn	47 45	18 12	1850·0	12 30 w.	0 55 w.	13·4 w.	63 40	+20	64·0	9·94	Kreil.
Funfkirchen	46 01	18 15	1850·0	12 36 w.	0 55 w.	13·5 w.	62 28	+20	62·8	9·85	Kreil.
Teschen	49 45	18 37	1850·0	12 35 w.	0 55 w.	13·5 w.	65 05	+20	65·4	10·03	Kreil.
Esseg	45 32	18 42	1850·0	12 18 w	0 55 w.	13·2 w.	62 00	+20	62·3	9·80	Kreil.
Tolna	46 25	18 49	1850·0	12 32 w.	0 55 w.	13·5 w.	62 47	+20	63·1	9·90	Kreil.
Schemnitz	48 27	18 55	1850·0	12 20 w.	0 55 w.	13·3 w.	64 04	+20	64·4	9·99	Kreil.
Ofen	47 29	19 03	1850·0	12 23 w.	0 55 w.	13·3 w.	63 30	+20	63·8	9·92	Kreil.
St. Miklos	49 04	19 40	1850·0	11 52 w.	0 55 w.	12·8 w.	64 35	+20	64·9	10·04	Kreil.
Losonetz	48 19	19 42	1850·0	11 32 w.	0 55 w.	12·5 w.	64 07	+20	64·5	10·02	Kreil.
Carlowitz	45 11	19 57	1850·0	11 01 w.	0 55 w.	12·0 w.	61 14	+20	61·6	9·90	Kreil.
Wieliczka	49 59	20 04	1850·0	11 45 w	0 55 w.	12·7 w.	65 14	+20	65·6	10·13	Kreil.
Szegedin	46 15	20 08	1850·0	11 20 w.	0 55 w.	12·3 w.	62 24	+20	62·7	9·85	Kreil.
Szolnok	47 10	20 15	1850·0	11 43 w.	0 55 w.	12·6 w.	63 10	+20	63·5	9·95	Kreil.
Erlau	47 53	20 23	1850·0	11 48 w.	0 55 w.	12·7 w.	63 31	+20	63·9	9·99	Kreil.
Kesmark	49 08	20 29	1850·0	11 25 w	0 55 w.	12·3 w.	64 40	+20	65·0	10·08	Kreil.
Sandec	49 34	20 34	1850·0	11 33 w.	0 55 w.	12·5 w.	64 46	+20	65·1	10·02	Kreil.
Leutschau	49 01	20 39	1850·0	11 19 w.	0 55 w.	12·2 w.	64 30	+20	64·8	10·06	Kreil.
Temesvar	45 45	21 01	1850·0	10 50 w.	0 55 w.	11·8 w.	61 41	+20	62·0	9·76	Kreil.
Kaschau	48 41	21 19	1850·0	11 02 w.	0 55 w.	12·0 w.	64 17	+20	64·6	10·04	Kreil.
Arad	46 11	21 19	1850·0	10 55 w.	0 55 w.	11·8 w.	62 00	+20	62·3	9·78	Kreil.
Tokay	48 07	21 28	1850·0	10 48 w.	0 55 w.	11·7 w.	63 20	+20	63·7	9·91	Kreil.
Debreczin	47 32	21 41	1850·0	10 44 w.	0 55 w.	11·7 w.	63 10	+20	63·5	9·94	Kreil.
Krosno	49 41	21 47	1850·0	11 01 w.	0 55 w.	11·9 w.	64 46	+20	65·1	10·02	Kreil.
Groswardein	47 04	21 59	1850·0	10 54 w.	0 55 w.	11·8 w.	62 47	+20	63·1	9·89	Kreil.

ZONE II.—Lat. 45° to 50° N. (continued).

	° ′	° ′		° ′	° ′	°	°	° ′	′	°				
Karansebes	45 24	22 12	1850·0	10 25 w.	0 55 w.	11·3 w.		61 06	+20	61·4		9·70		Kreil.
Sanok	49 33	22 13	1850·0	10 17 w.	0 55 w.	11·2 w.		64 42	+20	65·0		10·06		Kreil.
Ungvar	48 37	22 22	1850·0	10 24 w.	0 55 w.	11·3 w.		63 47	+20	64·1		10·00		Kreil.
Dobra	45 54	22 33	1850·0	10 15 w.	0 55 w.	11·2 w.		61 34	+20	61·9		9·79		Kreil.
Munkacz	48 26	22 47	1850·0	10 17 w.	0 55 w.	11·2 w.		63 40	+20	64·0		9·96		Kreil.
Przemisl	49 47	22 49	1850·0	9 37 w.	0 55 w.	10·5 w.		64 49	+20	65·1		10·14		Kreil.
Szatmer	47 47	22 56	1850·0	10 11 w.	0 55 w.	11·1 w.		63 18	+20	63·6		9·98		Kreil.
Veretzke	48 46	23 08	1850·0	9 47 w.	0 55 w.	10·7 w.		63 55	+20	64·3		9·98		Kreil.
Sambor	49 31	23 13	1850·0	9 28 w.	0 55 w.	10·4 w.		64 32	+20	64·9		10·05		Kreil.
Skole	49 01	23 34	1850·0	9 31 w.	0 55 w.	10·4 w.		64 05	+20	64·4		10·05		Kreil.
Nagybanya	47 39	23 38	1850·0	9 51 w.	0 55 w.	10·8 w.		62 52	+20	63·2		9·98		Kreil.
Karlsburg	46 04	23 39	1850·0	9 42 w.	0 55 w.	10·6 w.		61 37	+20	61·9		9·89		Kreil.
Klausenburg	46 45	23 40	1850·0	9 54 w.	0 55 w.	10·8 w.		62 21	+20	62·7		9·90		Kreil.
Stry	49 15	23 53	1850·0	9 24 w.	0 55 w.	10·3 w.		64 12	+20	64·5		10·08		Kreil.
Lemberg	49 50	24 02	1850·0	9 11 w.	0 55 w.	10·1 w.		64 40	+20	65·0		10·07		Kreil.
Dolina	48 58	24 04	1850·0	9 06 w.	0 55 w.	10·0 w.		64 02	+20	64·4		10·05		Kreil.
Hermannstadt	45 47	24 13	1850·0	9 33 w.	0 55 w.	10·5 w.		61 17	+20	61·6		9·86		Kreil.
Bistriz	47 07	24 33	1850·0	9 50 w.	0 55 w.	10·8 w.		62 34	+20	62·9		9·95		Kreil.
Maros Vasarhely	46 32	24 38	1850·0	10 12 w.	0 55 w.	11·1 w.		62 15	+20	62·6		9·95		Kreil.
Stanislau	48 55	24 45	1850·0	9 05 w.	0 55 w.	10·0 w.		63 55	+20	64·3		10·04		Kreil.
Schassburg	46 13	24 52	1850·0	10 10 w.	0 55 w.	11·1 w.		61 43	+15	62·0		9·91		Kreil.
Fogaros	45 50	25 03	1850·0	9 41 w.	0 55 w.	10·6 w.		61 20	+15	61·6		9·85		Kreil.
Kolomea	48 31	25 05	1850·0	9 03 w.	0 55 w.	10·0 w.		63 29	+15	63·7		9·97		Kreil.
Jakobeny	47 26	25 23	1850·0	8 50 w.	0 55 w.	9·8 w.		62 35	+15	62·8		9·95		Kreil.
Tarnopol	49 33	25 37	1850·0	9 17 w.	0 55 w.	10·2 w.		64 23	+15	64·6		10·07		Kreil.
Czortkow	49 01	25 50	1850·0	8 50 w.	0 55 w.	9·8 w.		63 33	+15	63·8		10·00		Kreil.
Czernowitz	48 17	26 01	1850·0	9 26 w.	0 55 w.	10·4 w.		63 21	+15	63·6		10·05		Kreil.
Suczawa	47 38	26 19	1850·0	8 50 w.	0 55 w.	9·8 w.		62 44	+15	63·0		9·96		Kreil.
Busio	45 09	26 48	1829·0	12 30 w.	1 30 E.	11·0 w.		......	......	......		......		Russian Officers.
Butuschan	47 45	26 50	1831·0	9 44 w.	1 17 E.	8·5 w.		......	......	......		......		Russian Officers.
Roman	46 55	26 55	1828·0	11 31 w.	1 38 E.	9·9 w.		......	......	......		......		Russian Officers.
Jokshan	45 42	27 10	1829·0	11 19 w.	1 30 E.	9·8 w.		......	......	......		......		Russian Officers.
Jassi	47 10	27 35	1828·0	11 51 w.	1 38 E.	10·2 w.		......	......	......		......		Russian Officers.
Berlat	46 14	27 39	1830·0	10 45 w.	1 24 E.	9·4 w.		......	......	......		......		Russian Officers.
Brailow	45 16	27 58	1830·0	10 43 w.	1 24 E.	9·3 w.		......	......	......		......		Russian Officers.
Galatz	45 26	28 03	1830·0	10 43 w.	1 24 E.	9·3 w.		......	......	......		......		Russian Officers.
			1838·5	......	......	......	9·0 w.	61 15	......	61·3	61·4	......		Ainsworth.
			1850·0	7 40 w.	0 56 w.	8·6 w.		61 31	......	61·5		9·99		Kreil.
Kilia	45 26	29 20	1828·0	8 53 w.	1 38 E.	7·3 w.		......	......	......		......		Russian Officers.
Sulina	45 09	29 42	1850·0	7 18 w.	0 48 w.	8·1 w.		......	......	......		......		Kreil.
Serpent's Island	45 14	30 13	1850·0	6 52 w.	0 48 w.	7·7 w.		60 41	......	60·7		10·04		Kreil.
Thiodousi Island	45 16	30 15	1859·5	5 34 w.	1 42 w.	7·3 w.		59 49	......	59·8		......		Dirkoff.
Odessa	46 29	30 43	1830·0	10 30 w.	1 12 E.	9·3 w.		......	......	......		......		Marigny.
			1850·0	8 37 w.	0 45 w.	9·4 w.	9·2 w.	62 09	......	62·2	61·8	10·44		Kreil.
			1859·0	7 22 w.	1 39 w.	9·0 w.		61 32	......	61·5		......		Dirkoff.
Otchakoff	46 37	31 32	1859·5	5 49 w.	1 42 w.	7·5 w.		......	......	......		......		Dirkoff.
Nicolaieff	46 59	31 58	1859·5	4 43 w.	1 42 w.	6·4 w.		61 14	......	61·2		......		Dirkoff.
Ak Mechel	45 30	32 42	1859·5	4 31 w.	1 42 w.	6·2 w.		60 08	......	60·1		......		Dirkoff.
Eupatoria	45 14	33 25	1859·5	4 32 w.	1 42 w.	6·2 w.		......	......	......		......		Dirkoff.
Theodosia	45 03	35 22	1820·5	8 10 w.	2 12 E.	6·0 w.	5·7 w.	......	......	......		......		Gauttier.
			1859·5	3 42 w.	1 42 w.	5·4 w.		......	......	......		......		Dirkoff.
Cape Takli	45 06	36 27	1850·0	4 21 w.	0 45 w.	5·1 w.		60 14	......	60·2		......		Kreil.
Kertch	45 22	36 31	1859·5	2 56 w.	1 42 w.	4·6 w.		......	......	......		......		Dirkoff.
Zaritzin	48 42	44 30	1830·0	1 53 w.	1 12 E.	0·7 w.		62 14	......	62·2		10·25		Hansteen.
			1830·0	1 52 w.	1 12 E.	0·7 w.	0·7 w.	......	......	......	62·4	......	10·25	Sawalief.
			1850·0	......	......	......		62 40	......	62·7		10·19		Sawalief.
			1869·5	2 10 E.	2 45 w.	0·6 w.		62 24	......	62·4		10·32		Wild.
Sarepta	48 30	44 36	1829·5	......	......	......		62 16	+06	62·4		......		Humboldt.
Winsowskoie	48 19	45 33	1830·0	......	......	......		61 56	+06	62·0		10·25		Due.
Tschernoi Jarr	48 04	46 14	1830·0	1 38 w.	0 48 E.	0·8 w.		61 55	+06	62·0		10·27 10·30	10·28	Hansteen.
Kopanowskaia	47 25	46 58	1830·0	......	......	......		61 13	+06	61·3		10·21		Hansteen.

ZONE II.—Lat. 45° to 50° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.		Inclination. Observed.	Inclination. Correction to Epoch 1842·5.	Inclination. Corrected.		Force in British units.		Observers.
	° ′	° ′		° ′	° ′	°	°	° ′	′	°	°			
Seroglasinskaia	46 59	47 29	1830·0	......	......	......		60 43	+06	60·8		10·20		Hansteen.
Dschangor Chan	48 46	47 32	1830·0	0 50 w.	0 48 E.	0·0		62 23	+06	62·5		10·40		Hansteen.
Birutchissa Island	45 44	47 39	1829·5	......	......	......	0·2 E.	59 21	+06	59·5	59·5	......	[illegible]	[illegible]
			1862·5	1 53 E.	1 40 w.	0·2 E.		59 40	−10	59·5		10·28		[illegible]
Astrachan	46 21	48 05	1829·5	......	......	......	0·0	59 58	+06	60·1	60·2	......	10·33	Humboldt.
			1830·5	1 12 w.	0 48 E.	0·4 w.		60 06	+06	60·2		......		Hansteen.
			1850·5	......	......	......		60 28	−04	60·4		......		[illegible]
			1862·5	2 05 E.	1 40 w.	0·4 E.		60 23	−10	60·2		10·33		Ivatinsk.
Geimenoi	48 57	49 48	1830·0	0 20 E.	0 48 E.	1·1 E.		62 27	+06	62·6		10·44		Hansteen.
N. Coast of Caspian	46 41	50 09	1862·5	2 50 E.	1 40 w.	1·2 E.		60 57	−10	60·8		......		Ivatinsk.
Kisilibinskoi	49 36	50 34	1830·0	0 49 E.	0 48 E.	1·6 E.		62 54	+06	63·0		10·43		Hansteen.
[illegible]	[illegible] 26	50 35	1830·0	0 50 E.	0 48 E.	1·6 E.		......	......	......		......		Hansteen.
[illegible]	45 00	51 10	1862·5	2 59 E.	1 40 w.	1·3 E.		59 05	−10	58·9		10·31		Ivatinsk.
Mergenew	49 56	51 16	1830·0	1 17 E.	0 48 E.	2·1 E.		63 11	+06	63·3		10·53		Hansteen.
Rakutchenaya	47 06	51 56	1862·5	3 53 E.	1 40 w.	2·2 E.		61 21	−10	61·2		10·41		Ivatinsk.
Ust Kamenogorsk	49 57	82 35	1829·5	......	......	......	7·0	64 48	+26	65·2	65·2	......		Humboldt.
			1834·5	7 02 E.	......	7·0 E.		64 57	+16	65·2		......		Fedorow.
Baingol	48 52	105 23	1830·5	......	......	......		65 14	+30	65·7		12·11		Fuss.
Chunzal	48 13	106 26	1831·5	1 06 E.	......	1·1 E.		64 30	+28	65·0		11·97		Fuss.
Urga	47 56	106 41	1831·5	1 16 E.	......	1·3 E.	1·3 E.	64 05	+28	64·6	64·6	11·75	11·89	Fuss.
			1868·0	1 13 E.	......	1·2 E.		65 41	−64	64·6		12·02		Fritsche.
Chapschatu	47 20	107 05	1831·5	......	......	......		63 21	+28	63·8		11·74		Fuss.
[illegible]	47 47	107 17	1831·5	......	......	......		63 39	+28	64·1		11·81		Fuss.
[illegible]	46 31	107 55	1831·5	......	......	......		62 59	+28	63·5		11·74		Fuss.
[illegible]	46 21	108 01	1831·5	0 02 w.	0 05 w.	0·1 w.		......	......	......		......		Fuss.
[illegible]	49 58	108 12	1832·5	0 12 E.	0 05 w.	0·1 E.		......	......	......		......		Fuss.
Chapchaktu	46 02	108 34	1831·5	......	......	......		62 24	+28	62·9		11·42		Fuss.
Giltegentai	46 54	108 45	1830·5	......	......	......		63 13	+30	63·7		11·84		Fuss.
[illegible]	45 50	108 52	1831·5	......	......	......		61 49	+28	62·3		11·47		Fuss.
Mendshinskoi	49 26	108 54	1832·5	0 12 w.	0 05 w.	0·3 w.		65 31	+25	65·9		12·10		Fuss.
[illegible]	45 34	109 15	1831·5	......	......	......		61 44	+28	62·2		11·46		Fuss.
[illegible]	46 29	109 37	1830·5	......	......	......		62 34	+30	63·1		11·95		Fuss.
[illegible]	45 08	109 41	1831·5	......	......	......		61 12	+28	61·7		11·46		Fuss.
[illegible]	[illegible] 16	110 09	1830·5	......	......	......		62 38	+30	63·1		11·62		Fuss.
Chologur	46 00	110 33	1832·0	0 49 w.	0 07 w.	0·9 w.		61 54	+25	62·3		11·73		Fuss.
Durbanderetu	45 48	111 13	1832·5	......	......	......		61 47	+25	62·2		11·76		Fuss.
Ergi	45 32	111 24	1832·5	1 08 w.	0 07 w.	1·3 w.		61 22	+25	61·8		11·58		Fuss.
Alsanskoi	49 28	111 29	1832·5	0 48 w.	0 07 w.	0·9 w.		65 21	+25	65·8		12·04		Fuss.
Abagaitujewskoi	49 35	117 49	1832·5	2 54 w.	0 07 w.	3·0 w.		64 48	+25	65·2		11·77		Fuss.
At sea	49 36	157 53	1849·5	5 22 E.	......	5·4 E.		......	......	......		......		Kellett.
At sea	48 49	158 13	1849·5	4 23 E.	......	4·4 E.		......	......	......		......		Kellett.
At sea	45 27	159 02	1827·5	3 58 E.	......	4·0 E.		57 56	......	57·9		9·74		Lütke.
At sea	47 28	159 45	1849·5	4 00 E.	......	4·0 E.		......	......	......		......		Kellett.
At sea	47 16	160 55	1828·0	3 13 E.	......	3·2 E.		......	......	......		......		Lütke.
At sea	45 33	161 05	1849·5	4 30 E.	......	4·5 E.		......	......	......		......		Kellett.
At sea	48 50	162 01	1850·0	4 37 E.	......	4·6 E.		......	......	......		......		Kellett.
At sea	48 34	164 38	1851·5	7 10 E.	......	7·2 E.		......	......	......		......		Collinson.
At sea	49 31	165 18	1851·5	......	......	......		60 46	......	60·8		......		Collinson.
At sea	49 58	166 25	1850·5	......	......	......		61 57	......	62·0		......		Collinson.
At sea	49 12	167 08	1854·5	......	......	......		61 30	......	61·5		......		Collinson.
At sea	46 19	169 50	1848·5	......	......	......		59 42	......	59·7		......		Moore.
At sea	45 04	170 23	1848·5	......	......	......		57 17	......	57·3		......		Moore.
At sea	48 10	170 27	1848·5	......	......	......		60 19	......	60·3		......		Moore.
At sea	48 31	171 06	1848·5	......	......	......		60 58	......	61·0		......		Moore.
At sea	48 15	171 09	1829·5	10 25 E.	......	10·4 E.		......	......	......		......		Erman.
At sea	47 04	176 36	1829·5	13 03 E.	......	13·1 E.		......	......	......		......		Erman.
At sea	47 58	186 47	1829·5	13 07 E.	......	13·1 E.		......	......	......		......		Erman.
At sea	48 50	190 34	1852·5	15 52 E.	......	15·9 E.		......	......	......		......		Crane.
At sea	46 16	191 07	1852·5	16 10 E.	......	16·2 E.		......	......	......		......		Crane.
At sea	48 41	193 00	1850·0	17 05 E.	......	17·1 E.		......	......	......		......		Kellett.
At sea	46 56	196 53	1850·0	17 34 E.	......	17·6 E.		......	......	......		......		Kellett.
At sea	49 54	197 34	1829·5	21 01 E.	......	21·0 E.		......	......	......		......		Erman.
At sea	45 19	200	1850·0	17 46 E.	......	17·8 E.		......	......	......		......		Kellett.
At sea	45 14	200 19	1850·0	18 45 E.	......	18·8 E.		......	......	......		......		Kellett.
At sea	48 08	213 21	1827·5	22 35 E.	......	22·6 E.		......	......	......		......		Lütke.

ZONE II.—Lat. 45° to 50° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Correction to Epoch 1842·5.	Corrected.		Inclination. Observed.	Correction to Epoch 1842·5.	Corrected.		Force in British Units.		Observers.
	° ′	° ′		° ′	° ′	°		° ′		°				
At sea........	48 41	216 37	1827·5	23 01 E.	......	23·0 E.		68 26	......	68·4		12·36		[illegible]
At sea....................	48 27	225 55	1829·5	21 55 E.	......	21·9 E.		......	......	......		......		Erman.
[illegible] Bay	49 15	234 04	1861·5	22 39 E.	1 35 W.	21·1 E.		72 37	......	72·6		......		Richards.
New Dungeness Light ..	48 11	234 51	1856·5	21 43 E.	1 10 W.	20·6 E.		......	......	......		......		U. S. Coast Survey.
[illegible]	49 00	235 00	1861·5	21 13 E.	1 35 W.	22·6 E.		......	......	......		......		Richards.
Henry Bay	49 36	235 09	1860·5	......				72 25	......	72·4		......		Richards.
[illegible]	49 14	235 10	1861·5	21 57 E.	1 15 W.	23·1 E.		......	......	......		......		Richards.
[illegible]	48 23	235 16	1852·5	21 30 E.	1 46 W.	19·8 E.		......	......	......		......		U. S. Coast Survey.
Neah Bay..............	48 22	235 23	1855·5	21 47 E.	1 05 W.	20·7 E.	20·7 E.	71 07	......	71·1	71·2	13·21	13·21	U. S. Coast Survey.
			1855·5	......	......	......		71 16	......	71·3		......		[illegible]
Cape Disappointment ..	46 17	235 58	1830·5	......	......	......	19·8 E.	69 30	......	69·5	69·5	12·52	12·45	Douglas.
			1839·5	19 12 E.	0 15 E.	19·5 E.		69 27	......	69·5		12·39		Belcher.
			1842·5	20 00 E.	......	20·0 E.		......	......	......		......		Duplot de Mofras.
			1851·5	20 32 E.	0 45 W.	19·8 E.		......	......	......		......		U. S. Coast Survey.
Portland (Oregon) ...	45 31	236 00	1858·5	20 00 E.	1 20 W.	18·7 E.		69 31	......	69·5		......		Friesach.
Namaimo	49 10	236 00	1862·5	22 57 E.	1 40 W.	21·3 E.		71 54	......	71·9		......		Richards.
Whiffen Spit...........	48 22	236 16	1864·5	20 20 E.	1 28 W.	18·9 E.		......	......	......		......		Pender.
Point George...........	46 11	236 20	1830 0	......	......	......		69 17	......	69·3		......		Douglas.
Esquimalt	48 26	236 33	1859·5	21 58 E.	0 51 W.	21·1 E.	21·1 E.	71 34	......	71·6	71·7	13·15		Haig.
			1862·5	......	......	......		71 52	......	71·9		......		Richards.
			1864·0	22 10 E.	1 05 W.	21·1 E.		......	......	......		......		Pender.
Victoria	48 26	236 35	1858·5	21 40 E.	0 48 W.	20·9 E.	21·1 E.	71 39	......	71·7	71·7	......		Friesach.
Laurel Point, Victoria	48 25	236 37	1862·5	22 18 E.	1 00 W.	21·3 E.		71 39	......	71·7		......		Richards.
Garry Pt. Fraser River	49 07	236 49	1864 5	22 58 E.	1 06 W.	21·9 E.		......	......	......		......		Pender.
Burrard Inlet	49 16	236 50	1859·5	......	......	......		72 14	......	72·2		......		Richards.
Semiahmoo Spit	48 59	237 00	1858·5	......	......	......		72 15	......	72·3		......		Richards.
Olympia..................	47 03	237 05	1856·5	20 47 E.	0 42 W.	20·1 E.		......	......	......		......		U. S. Coast Survey.
New Westminster......	49 13	237 07	1862·5	22 40 E.	1 00 W.	21·7 E.		72 15	......	72·3		......		Richards.
River Multnomah......	45 15	237 13	1830·0	......	......	......		68 57	......	69·0		12·42		Douglas.
Point Hudson	48 07	237 15	1856·5	21 39 E.	0 28 W.	21·2 E.		......	......	......		......		U. S. Coast Survey.
Fort Vancouver.........	45 37	237 32	1830·5	......	......	......	19·5 E.	69 40	......	69·7	69·5	12·63	12·76	Douglas.
			1839·5	19 22 E.	0 06 E.	19·5 E.		69 22	......	69·4		12·60		Belcher.
			1860·0	20 05 E.	0 35 W.	19·5 E.		69 17	......	69·3		13·05		Haig.
[illegible]	[illegible]	237 35	1859·0	21 23 E.	0 33 W.	20·8 E.		70 40	......	70·7		13·12		Haig.
[illegible]	[illegible]	237 48	1858·5	21 30 E.	0 32 W.	21·0 E.		72 22	......	72·4		13·23		Haig.
[illegible]	[illegible]	238 00	1859·5	21 37 E.	0 34 W.	21·1 E.		72 04	......	72·1		13·29		Haig.
[illegible]	[illegible]	238 12	1830·0	......	......	......		69 27	......	69·5		12·50		Douglas.
[illegible]	[illegible]	238 37	1860·0	......	......	......		72 31	......	72·5		13·18		Haig.
Dalles, 3 mile Camp ..	45 35	239 11	1860·0	......	......	......		69 42	......	69·7	69·9	......	13·09	Haig.
Dalles, 8 mile Camp ..	45 40	239 11	1860·0	......	......	......		70 05	......	70·1		......		Haig.
Ashtnolou River	49 10	240 00	1860·0	21 50 E.	0 35 W.	21·3 E.		72 37	......	72·6		13·23		Haig.
Ashtnolou Station......	49 00	240 00	1860·0	22 40 E.	0 35 W.	22·1 E.		72 27	......	72·5		13·32		Haig.
Oakanagan	48 05	240 33	1833·0	......	......	......		71 45	......	71·8		12·73		Douglas.
Osoyous..................	49 00	240 36	1860·0	22 14 E.	0 35 W.	21·7 E.		......	......	......		......		Haig.
River Walla Walla ...	46 03	241 12	1830 0	......	......	......		70 14	......	70·2		12·71		Douglas.
Fort Walla Walla......	46 04	241 12	1853·0	19 40 E.	0 21 W.	19·3 E.		......	......	......		......		U. S. Exploration.
Inshwointum............	49 00	241 32	1860·0	20 17 E.	0 35 W.	19·7 E.		72 49	......	72·8		13·27		Haig.
Fort Colville............	48 40	241 55	1860·0	21 40 E.	0 35 W.	21·1 E.		72 42	......	72·7		13·40		Haig.
[illegible] River	48 00	242 15	1861·0	21 28 E.	0 37 W.	20·9 E.		72 04	......	72·1		13·34		Haig.
[illegible]	48 09	243 16	1861·0	21 16 E.	0 37 W.	20·7 E.		72 35	......	72·6		13·37		Haig.
Pack River	48 22	243 32	1861·0	22 51 E.	0 37 W.	22·2 E.		72 46	......	72·8		13·39		Haig.
[illegible]	48 41	243 41	1861·0	22 11 E.	0 37 W.	21·6 E.		73 08	......	73·1		13·47		Haig.
Kootenay, S. Crossing .	48 22	244 39	1860·0	22 16 E.	0 35 W.	21·7 E.		72 48	......	72·8		13·44		Haig.
On Kootenay River ...	48 40	244 43	1861·0	23 24 E.	0 37 W.	22·8 E.		73 07	......	73·1		13·44		Haig.
Tobacco Plains.........	48 57	244 52	1861·0	......	......	......		73 23	......	73·4		13·50		Haig.
Wigwam River.........	49 00	245 15	1861·0	23 52 E.	0 19 W.	23·6 E.		73 31	......	73·5		13·50		Haig.
Akamina	49 01	245 56	1861·0	23 12 E.	0 19 W.	22·9 E.		73 43	......	73·7		13·50		Haig.
Fort Owen..............	46 31	246 02	1853·0	19 25 E.	......	19·4 E.		......	......	......		......		U. S. Exploration.
Fort Benton	47 52	249 24	1853·0	19 00 E.	......	19·0 E.		......	......	......		......		
Fort Union	48 00	256 01	1853·0	16 48 E.	......	16·8 E.		......	......	......		......		

ZONE II.—Lat. 45° to 50° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.		Inclination. Observed.	Inclination. Correction to Epoch 1842·5.	Inclination. Corrected.		Force in British units.	Observers.
	° ′	° ′		° ′	° ′	°		° ′		°			
Upper Fort Garry ...	49 53	262 58	1843·5	16 00 E.	0 03 E.	16·1 E.		78 18	......	78·3		14·07	Lefroy.
Halting Place	49 26	265 12	1857·5	10 17 E.	0 45 E.	11·0 E.		......	......	......		......	Palliser.
Lake of the Woods ...	49 19	265 18	1843·5	......	......	......		78 04	......	78·1		14·13	Lefroy.
Lake of the Woods ...	49 28	265 18	1843·5	12 53 E.	0 03 E.	12·9 E.		78 17	......	78·3		14·05	Lefroy.
Rat Portage	49 46	265 25	1843·5	......	......	......		78 08	......	78·1		14·01	Lefroy.
Rainy River	48 48	265 29	1843·5	13 07 E.	0 03 E.	13·2 E.		77 57	......	78·0		......	Lefroy.
Halting Place	48 50	266 02	1857·5	11 20 E.	0 45 E.	12·1 E.		......	......	......		......	Palliser.
			1843·5	10 38 E.	0 05 E.	10·7 E.		77 34	......	77·6		14·10	Lefroy.
Fort Francis...........	48 37	266 31	1845·5	......	......	......	10·7 E.	77 32	......	77·5	77·6	......	Rae.
			1857·5	9 31 E.	1 15 E.	10·8 E.		......	......	......		......	Palliser.
Rainy Lake	48 32	267 04	1843·5	11 28 E.	0 05 E.	11·6 E.		77 48	......	77·8		14·07	Lefroy.
Sturgeon Lake	48 27	267 19	1843·5	......	......	......		77 45	......	77·8		14·08	Lefroy.
Halting Place	48 27	267 30	1857·5	9 53 E.	1 15 E.	11·1 E.		......	......	......		......	Palliser.
[illegible]	48 15	267 33	1843·5	10 15 E.	0 05 E.	10·3 E.		77 40	......	77·7		14·04	Lefroy.
[illegible]	[illegible] 24	267 50	1843·5	7 53 E.	0 05 E.	8·0 E.		77 51	......	77·9		14·08	Lefroy.
[illegible]	[illegible] 43	267 50	1824·5	12 30 E.	1 30 W.	11·0 E.		......	......	......		......	Bayfield.
Point on Coast.........	46 42	268 10	1824·5	12 20 E.	1 30 W.	10·8 E.		......	......	......		......	Bayfield.
Point on Coast.........	46 48	268 30	1824·5	12 27 E.	1 30 W.	11·0 E.		......	......	......		......	Bayfield.
Two Rivers Portage...	48 35	268 33	1843·5	11 00 E.	0 05 E.	11·1 E.		77 49	......	77·8		13·99	Lefroy.
Perch Lake	48 35	268 48	1857·5	8 14 E.	1 15 E.	9·5 E.		......	......	......		......	Palliser.
French Portage.........	48 35	268 53	1843·5	......	......	......		78 20	......	78·3		14·08	Lefroy.
La Pointe	46 47	269 02	1843·5	......	......	......		76 56	......	76·9		14·19	Locke.
S. Point of Madeline Island	46 45	269 05	1824·5	9 48 E.	1 30 W.	8·3 E.		......	......	......		......	Bayfield.
Point on Coast.........	47 33	269 10	1824·5	10 30 E.	1 30 W.	9·0 E.		......	......	......		......	Bayfield.
			1843·5	......	......	......		78 22	......	78·4		14·13	Lefroy.
Savannah Portage......	48 53	269 52	1844·5	7 46 E.	0 10 E.	7·9 E.	8·0 E.	......	......	......		......	Lefroy.
			1857·5	6 53 E.	1 15 E.	8·1 E.		......	......	......		......	Palliser.
Point on Coast.........	46 48	269 59	1824·5	10 15 E.	1 30 W.	8·8 E.		......	......	......		......	Bayfield.
Prairie Portage.........	48 58	269 59	1843·5	......	......	......		78 26	......	78·4		14·12	Lefroy.
Trembling Portage ...	48 31	270 00	1857·5	6 21 E.	1 15 E.	7·6 E.		......	......	......		......	Palliser.
Halting Place	48 55	270 06	1857·5	9 05 E.	1 15 E.	10·3 E.		......	......	......		......	Palliser.
Halting Place	48 45	270 07	1857·5	8 54 E.	1 15 E.	10·2 E.		......	......	......		......	Palliser.
Grand Portage	47 58	270 11	1824·5	11 00 E.	1 30 W.	9·5 E.		......	......	......		......	Bayfield.
Portage Ecarté.........	48 25	270 15	1843·5	......	......	......		77 14	......	77·2		14·02	Lefroy.
[illegible] Portage	48 29	270 20	1843·5	5 33 E.	0 05 E.	5·6 E.		......	......	......		......	Lefroy.
Dog Lake	48 47	270 20	1843·5	6 26 E.	0 05 E.	6·5 E.		......	......	......		......	Lefroy.
Dog Portage	48 39	270 26	1843·5	......	......	......		78 27	......	78·5		14·14	Lefroy.
Ontanogon River	46 52	270 30	1824·5	8 40 E.	1 30 W.	7·2 E.		......	......	......		......	Bayfield.
			1843·5	......	......	......		77 13	......	77·2		14·12	Locke.
			1824·5	9 05 E.	1 30 W.	7·6 E.		......	......	......		......	Bayfield.
Fort William............	48 24	270 37	1844·5	6 21 E.	0 10 E.	6·5 E.	7·1 E.	78 06	......	78·1	78·1	14·01	Lefroy.
			1845·5	......	......	......		78 11	......	78·2		......	Rae.
Pointe Tonnerre	48 19	270 58	1843·5	......	......	......		78 23	......	78·4		14·20	Lefroy.
Little Trout River ...	47 09	271 06	1824·5	9 12 E.	1 30 W.	7·7 E.		......	......	......		......	Bayfield.
Mean of 5 Stations ...	47 29	271 10	1843·5	......	......	......		78 05	......	78·1		......	Locke.
Isle Royale	48 07	271 11	1824·5	9 39 E.	1 30 W.	8·2 E.		......	......	......		......	Bayfield.
			1843·5	......	......	......		78 08	......	78·1		14·30	Locke.
Eagle River	47 27	271 37	1843·5	......	......	......		77 55	......	77·9		14·08	Locke.
Mean of Stations	47 16	271 49	1843·5	......	......	......		77 44	......	77·7		......	Locke.
Huron River............	46 55	271 53	1824·5	7 56 E.	1 30 W.	6·4 E.		......	......	......		......	Bayfield.
Isle Saint Ignace	48 45	271 58	1824·5	8 15 E.	1 30 W.	6·8 E.		......	......	......		......	Bayfield.
Houghton's River.....	47 28	271 59	1843·5	......	......	......		77 17	......	77·3		13·94	Locke.
Point Keewai............	47 29	272 06	1824·5	7 32 E.	1 30 W.	6·0 E.		......	......	......		......	Bayfield.
Terre Platte	48 40	272 15	1843·5	5 40 E.	0 05 E.	5·8 E.		78 54	......	78·9		14·03	Lefroy.
Encampment............	46 44	272 17	1843·5	......	......	......		76 58	......	77·0		14·05	Locke.
Lake Superior	48 46	272 20	1844·5	......	......	......		78 24	......	78·4		......	Lefroy.
Small River	46 32	272 50	1824·5	7 21 E.	1 30 W.	5·9 E.		......	......	......		......	Bayfield.
Point on Coast	48 44	273 00	1824·5	7 42 E.	1 30 W.	6·2 E.		......	......	......		......	Bayfield.
Grand Island	46 27	273 18	1824·5	6 16 E.	1 30 W.	4·8 E.		......	......	......		......	Bayfield.
Fort Pic..................	48 38	273 21	1844·5	5 31 E.	0 10 E.	5·7 E.		78 38	......	78·6		13·90	Lefroy.
Peninsular Harbour...	48 44	273 32	1824·5	6 20 E.	1 30 W.	4·8 E.		78 34	......	78·6		......	Bayfield.

ZONE II.—Lat. 45° to 50° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.	Inclination. Observed.	Inclination. Correction to Epoch 1842·5.	Inclination. Corrected.	Force in British units.	Observers.
	° ′	° ′		° ′	° ′	°	° ′		°		
White River	48 33	273 33	1844·5	2 10 E.	0 10 E.	2·3 E.	78 33	......	78·6	14·12	Lefroy.
Otter Head	48 05	273 50	1824·5	5 07 E.	1 30 W.	3·6 E.	......	......	......	......	Bayfield.
Le Petit Mort	47 58	274 11	1843·5	4 59 E.	0 05 E.	5·1 E.	......	......	......	......	Lefroy.
South Manitou Island	45 05	274 22	1841·5	......	......	......	75 59	......	76·0 } 76·0	......	Loomis.
			1842·5	......	......	......	75 57	......	76·0	13·97	Younghusband.
Near Chienne River	47 52	274 36	1843·5	2 22 E.	0 05 E.	2·5 E.	......	......	......	......	Lefroy.
Gargantua	47 35	274 49	1824·5	4 06 E.	1 30 W.	2·6 E.	......	......	......	......	Bayfield.
			1844·0	......	......	......	77 56	......	77·9	......	Lefroy.
White Fish Point	46 46	274 54	1824·5	4 50 E.	1 30 W.	3·3 E.	......	......	......	......	Bayfield.
Michipicoton	47 56	274 56	1824·5	4 33 E.	1 30 W.	3·1 E. } 3·5 E.	......	......	......	......	Bayfield.
			1844·5	3 49 E.	0 10 E.	4·0 E.	78 07	......	78·1 } 78·1	13·98	Lefroy.
			1845·5	......	......	......	78 05	......	78·1	......	Rae.
Pointe au Crêpe	46 58	275 02	1843·5	2 15 E.	0 05 E.	2·3 E.	77 12	......	77·2	14·21	Lefroy.
Wangoshane Point	45 45	275 04	1853·5	2 13 E.	0 55 E.	3·1 E.	......	......	......	......	U. S. Coast Survey.
Old Michilimachinac Point	45 47	275 06	1824·5	5 02 E.	1 30 W.	3·5 E.	......	......	......	......	Bayfield.
Montreal Island	47 19	275 08	1824·5	3 28 E.	1 30 W.	2·0 E.	......	......	......	......	Bayfield.
Point Iroquois	46 29	275 13	1824·5	3 22 E.	1 30 W.	1·9 E.	......	......	......	......	Bayfield.
Gros Cap	46 32	275 17	1841·5	......	......	......	77 05	......	77·1	......	Loomis.
Machinac	45 51	275 19	1841·5	......	......	......	76 35	......	76·6	......	Nicollet.
			1841·5	......	......	......	76 38	......	76·6 } 76·6	14·10 } 14·10	Loomis.
			1843·5	......	......	......	76 39	......	76·7	......	Locke.
Pointe aux Pins	46 29	275 19	1843·0	......	......	......	77 13	......	77·2 } 77·2	14·09 } 14·09	Lefroy.
			1845·0	......	......	......	77 16	......	77·3	......	Rae.
Sault St. Marie	46 31	275 28	1843·0	......	......	......	......	......	......	14·08	Locke.
			1843·5	1 08 E.	0 05 E.	1·2 E. } 1·1 E.	......	......	...... } 77·3	......	Lefroy.
			1845·0	0 46 E.	0 13 E.	1·0 E.	......	......	......	13·98 } 14·03	Lefroy.
			1845·0	......	......	......	77 20	......	77·3	......	Rae.
Fort Brady	46 30	275 36	1841·5	......	......	......	77 30	......	77·5	......	Loomis.
Head of Lake George	46 32	275 40	1825·5	3 19 E.	1 25 W.	1·9 E.	......	......	......	......	Bayfield.
St. Joseph's Island	46 04	275 51	1822·5	3 00 E.	1 40 W.	1·3 E.	......	......	......	......	Bayfield.
Portlock Harbour	46 20	275 53	1822·5	2 51 E.	1 40 W.	1·2 E.	......	......	......	......	Bayfield.
Duncan City	45 36	275 53	1851·5	1 53 E.	0 45 E.	2·6 E.	......	......	......	......	U. S. Coast Survey.
Bear Encampment	46 20	276 04	1845·5	0 03 E.	0 15 E.	0·3 E.	......	......	......	......	Lefroy.
False Detour	45 53	276 18	1819·5	3 13 E.	1 55 W.	1·3 E.	......	......	......	......	Bayfield.
False Pass. d'Tour	15 18	276 23	1817·5	2 59 E.	2 05 W.	0·9 E.	......	......	......	......	Bayfield.
Thessalon Point	46 16	276 29	1843·5	0 31 W.	0 05 E.	0·4 W.	76 59	......	77·0	14·02	Lefroy.
Missesauga	46 08	276 50	1843·5	0 55 W.	0 05 E.	0·8 W.	......	......	......	......	Lefroy.
Cranberry Bay	46 11	276 57	1845·5	0 25 W.	0 15 E.	0·2 W.	......	......	......	......	Lefroy.
Snake Island	46 09	277 05	1843·5	......	......	......	77 06	......	77·1	13·87	Lefroy.
Pte. la Cloche	46 07	277 35	1843·5	1 58 W.	0 05 E.	1·9 W.	76 50	......	76·8	13·64	Lefroy.
S.E. Point of Manitoulin Island	45 28	278 06	1821·5	1 13 E.	1 45 W.	0·5 W.	......	......	......	......	Bayfield.
Cape Hurd	45 14	278 09	1821·5	0 21 E.	1 45 W.	1·4 W.	......	......	......	......	Bayfield.
Lake Huron	46 00	278 10	1843·5	......	......	......	77 06	......	77·1	13·93	Lefroy.
Rattlesnake Harbour	45 32	278 11	1821·5	0 50 E.	1 45 W.	0·9 W.	......	......	......	......	Bayfield.
S.W. Point of Bears Rump Island	45 19	278 20	1821·5	0 24 E.	1 45 W.	1·4 W.	......	......	......	......	Bayfield.
Point on Coast	45 57	278 22	1821·5	0 31 W.	1 45 W.	2·3 W.	......	......	......	......	Bayfield.
Half Moon Island	45 27	278 25	1821·5	0 22 E.	1 45 W.	1·4 W.	......	......	......	......	Bayfield.
Lake Huron	45 57	278 28	1843·5	0 38 W.	0 05 E.	0·6 W.	......	......	......	......	Lefroy.
White Shingle Bank	45 37	278 29	1821·5	0 21 E.	1 45 W.	1·4 W.	......	......	......	......	Bayfield.
Cabot's Head, Wingfield Basin	45 15	278 34	1819·5	0 24 E.	1 55 W.	1·5 W.	......	......	......	......	Bayfield.
Chin Cape	45 07	278 35	1819·5	0 39 E.	1 55 W.	1·3 W.	......	......	......	......	Bayfield.
Point au Croix	45 55	278 42	1843·5	......	......	......	76 31	......	76·5	14·02	Lefroy.
Islet off Pt. Grondine	45 54	278 45	1821·5	0 32 W.	1 45 W.	2·3 W.	......	......	......	......	Bayfield.
Ricolet Falls	45 57	278 59	1843·5	......	......	......	76 45	......	76·8	14·15	Lefroy.
Islet off Henvey Inlet	45 51	279 07	1821·5	1 33 E.	1 45 W.	0·2 W.	......	......	......	......	Bayfield.
Islet off Franklin Inlet	45 33	279 22	1821·5	0 40 E.	1 45 W.	1·1 W.	......	......	......	......	Bayfield.
Western Isles	45 05	279 35	1820·5	1 25 E.	1 50 W.	0·4 W.	......	......	......	......	Bayfield.
Lake Nipissing	46 13	280 01	1843·5	......	......	......	77 10	......	77·2	13·90	Lefroy.
Lac du Grand Vase	46 18	280 34	1843·5	......	......	......	77 22	......	77·4	13·97	Lefroy.

ZONE II.—Lat. 45° to 50° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.		Inclination. Observed.	Inclination. Correction to Epoch 1842·5.	Inclination. Corrected.		Force in British units.		Observers.
	° ′	° ′		° ′	° ′	°		° ′		°				
Portage du Grand Vase	46 19	280 53	1843·5	3 52 W.	0 05 E.	3·8 W.		......	......	......		......		Lefroy.
Little River	46 18	281 17	1843·5	......	......	......		77 29	......	77·5		13·91		Lefroy.
[illegible]	46 15	281 27	1843·5	......	......	......		77 24	......	77·4		13·93		Lefroy.
[illegible]	46 15	281 40	1843·5	4 48 W.	0 05 E.	4·7 W.		......	......	......		......		Lefroy.
Deux Joachim's Point.	46 12	281 41	1843·5	......	......	......		77 04	......	77·1		13·85		Lefroy.
[illegible]	46 06	282 34	1843·5	......	......	......		77 27	......	77·5		13·79		Lefroy.
[illegible]	45 56	283 04	1843·5	......	......	......		77 30	......	77·5		13·95		Lefroy.
[illegible]	45 36	283 07	1843·5	5 11 W.	0 05 E.	5·1 W.		......	......	......		......		Lefroy.
Grand Calumet	45 45	283 20	1843·5	......	......	......		76 44	......	76·7		13·82		Lefroy.
[illegible]	[illegible] 26	283 28	1843·5	......	......	......		......	......	......		13·93		Lefroy.
[illegible]	[illegible] 29	284 12	1843·5	6 58 W.	0 05 E.	6·9 W.		76 41	......	76·7		13·81		Lefroy.
[illegible]	[illegible] 37	284 48	1843·5	6 58 W.	0 05 E.	6·9 W.		......	......	......		......		Lefroy.
[illegible]	[illegible] 37	285 05	1843·5	7 28 W.	0 05 E.	7·4 W.		76 55	......	76·9		13·66		Lefroy.
Cornwall	45 02	285 13	1845·0	......	......	......		76 16	......	76·3		13·79		Younghusband.
[illegible]	[illegible] 36	285 28	1843·5	8 41 W.	0 05 E.	8·6 W.		......	......	......		......		Lefroy.
[illegible]	[illegible] 36	285 38	1843·5	8 26 W.	0 05 E.	8·4 W.		......	......	......		......		Lefroy.
La Combes	45 32	285 51	1843·5	......	......	......		76 51	......	76·9		13·81		Lefroy.
Montreal and St. Helen's	45 30	286 25	1834·5	8 00 W.	0 40 W.	8·7 W.	° 8·9 W.	......	......	......	° 77·1	......	13·65	Bayfield.
			1842·5	8 58 W.	......	9·0 W.		77 09	......	77·2		13·78		Lefroy.
			1843·5	......	......	......		......	......	......		13·62		Bache.
			1845·5	......	......	......		77 09	......	77·2		13·53		Younghusband.
			1859·5	......	......	......		76 51	......	76·9		13·68		Officers of U. S.
[illegible]	45 00	286 40	1844·5	11 28 W.	0 10 E.	11·3 W.		76 40	......	76·7		......		Graham.
[illegible]	46 06	286 53	1830·5	10 27 W.	1 00 W.	11·5 W.		......	......	......		......		Bayfield.
[illegible]	46 06	286 58	1830·5	10 30 W.	1 00 W.	11·5 W.		......	......	......		......		Bayfield.
Sorel	46 03	287 00	1830·5	11 00 W.	1 00 W.	12·0 W.	11·7 W.	......	......	......	77·3	......	13·74	Bayfield.
			1842·5	11 22 W.	......	11·4 W.		77 17	......	77·3		13·74		Lefroy.
St. John's	45 19	287 00	1842·5	11 22 W.	......	11·4 W.		77 00	......	77·0		......		Lefroy.
Ice, Lake St. Peter	46 14	287 16	1828·5	11 15 W.	1 10 W.	12·4 W.		......	......	......		......		Bayfield.
River St. Maurice	46 21	287 17	1835·5	11 32 W.	0 35 W.	12·1 W.		......	......	......		......		Bayfield.
Three Rivers	46 19	287 24	1842·5	11 58 W.	......	12·0 W.		77 11	......	77·2		13·82		Lefroy.
Drummondville	45 53	287 26	1842·5	12 28 W.	......	12·5 W.		......	......	......		......		Lefroy.
Ile Bigot	46 26	287 36	1835·5	12 52 W.	0 35 W.	13·5 W.		......	......	......		......		Bayfield.
River Champlain	46 27	287 36	1835·5	12 31 W.	0 35 W.	13·1 W.		......	......	......		......		Bayfield.
Grondine	46 34	287 36	1835·5	12 27 W.	0 35 W.	13·0 W.		......	......	......		......		Bayfield.
Lake Memphremagog	45 01	287 41	1845·5	......	......	......		76 09	......	76·2		......		Whipple.
Stanstead	45 02	287 50	1842·5	......	......	......		76 20	......	76·3		13·61		Lefroy.
			1845·5	11 33 W.	0 15 E.	11·3 W.		......	......	......		......		[illegible]
[illegible]	46 10	288 06	1837·5	12 52 W.	0 25 W.	13·3 W.		......	......	......		......		[illegible]
[illegible]	45 01	288 39	1845·5	12 22 W.	0 15 E.	12·1 W.		76 24	......	76·4		......		Graham.
Quebec	46 49	288 41	1834·0	14 14 W.	0 42 W.	14·9 W.	14·7 W.	......	......	......	77·2	......	13·68	Bayfield.
			1842·5	14 12 W.	......	14·2 W.		77 15	......	77·3		13·80		Lefroy.
			1845·5	......	......	......		77 09	......	77·1		13·63		Younghusband.
			1859·5	16 17 W.	1 25 E.	14·9 W.		77 18	......	77·3		13·61		U. S. C. Survey.
Prospect Hill	45 15	288 46	1845·5	12 17 W.	0 15 E.	12·0 W.		......	......	......		......		Boundary Survey.
Connecticut River	45 15	288 47	1845·5	12 00 W.	0 15 E.	11·8 W.		......	......	......		......		Boundary Survey.
Highland Boundary	45 18	288 55	1845·5	13 20 W.	0 15 E.	13·1 W.		......	......	......		......		Boundary Survey.
Arnold's River	45 20	289 05	1845·5	13 30 W.	0 15 E.	13·3 W.		......	......	......		......		Boundary Survey.
Dead River	45 26	289 12	1845·5	13 10 W.	0 15 E.	12·9 W.		......	......	......		......		Boundary Survey.
Highland Boundary	45 31	289 17	1845·5	13 25 W.	0 15 E.	13·2 W.		......	......	......		......		Boundary Survey.
Highland Boundary	45 37	289 23	1844·5	13 37 W.	0 10 E.	13·5 W.		......	......	......		......		Boundary Survey.
Crane Island	47 05	289 28	1831·5	14 28 W.	0 55 W.	15·4 W.	14·7 W.	......	......	......		......		Bayfield.
At sea	47 08	289 28	1842·5	14 00 W.	......	14·0 W.		......	......	......		......		Lefroy.
Highland Boundary	45 42	289 32	1844·5	13 50 W.	0 10 E.	13·7 W.		......	......	......		......		Boundary Survey.
Ile aux Coudres	47 25	289 34	1831·5	15 17 W.	0 55 W.	16·2 W.		......	......	......		......		Bayfield.
Taschereaus	45 49	289 36	1844·5	14 07 W.	0 10 E.	14·0 W.		76 50	......	76·8		......		Graham.
Stone Pillar	47 12	289 38	1831·5	14 49 W.	0 55 W.	15·7 W.		......	......	......		......		Bayfield.
At sea	47 20	289 42	1842·5	14 16 W.	......	14·3 W.		......	......	......		......		Lefroy.
Moose River	45 39	289 44	1844·5	......	......	......		76 49	......	76·8		......		Graham.
St. John's River	46 25	289 56	1844·5	......	......	......		77 25	......	77·4		......		Graham.

ZONE II.—Lat. 45° to 50° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.		Inclination. Observed.	Inclination. Correction to Epoch 1842·5.	Inclination. Corrected.		Force in British units.		Observers.
	° ′	° ′		° ′	° ′	°		° ′		°				
River St. Croix	46 25	289 57	1844·5	15 02 w.	0 10 E.	14·9 w.		......	......	......		......		Boundary Survey.
Forks of Kennebec ..	45 20	290 02	1841·5	......	......	......		76 21	......	76·4		......		Graham.
Grand Forks of St. John	46 55	290 07	1841·5	......	......	......		77 26	......	77·4		......		Graham.
Tadousac	48 09	290 16	1829·5	17 35 w.	1 05 w.	18·7 w.		......	......	......		......		Bayfield.
Brandy-Pot Island ...	47 53	290 18	1830·5	17 15 w.	1 00 w.	18·3 w.	18·1 w.	78 35	......	78·6		......		Bayfield.
			1836·5	17 25 w.	0 30 w.	17·9 w.		......	......	......		......		Bayfield.
Rivière du Loup	47 51	290 25	1831·5	17 36 w.	0 55 w.	18·5 w.		......	......	......		......		Bayfield.
Big Black River	46 57	290 33	1841·5	16 2[illegible]	0 10 [illegible]	16·3 w.		77 38	......	77·6		......		Graham.
Lake Pohenagamook .	47 28	290 47	1843·5	......	......	......		77 49	......	77·8		......		Graham.
Razade Isle	48 13	290 51	1829·5	17 31 w.	1 05 w.	18·7 w.		......	......	......		......		Bayfield.
Port Neuf	48 37	290 53	1831·5	17 36 w.	0 55 w.	18·5 w.		......	......	......		......		Bayfield.
Little Black River ..	47 07	290 55	1841·5	......	......	......		77 41	......	77·7		......		Graham.
Beau Lac	47 23	290 57	1843·5	......	......	......		77 47	......	77·8		......		Graham.
River St. Francis	47 14	290 59	1843·5	17 24 w.	0 05 E.	17·3 w.		......	......	......		......		Boundary Survey.
River St. Francis	47 11	291 04	1842·5	17 03 w.	......	17·1 w.		......	......	......		......		Boundary Survey.
River St. Francis	47 11	291 06	1843·5	......	......	......		77 44	......	77·7		......		Graham.
Bic Island	48 25	291 11	1830·5	17 29 w.	1 00 w.	18·5 w.		......	......	......		......		Bayfield.
Savage Island	47 16	291 16	1842·5	17 58 w.	......	18·0 w.		......	......	......		......		Boundary Survey.
Bersimis Point	48 56	291 22	1831·5	18 48 w.	0 55 w.	19·7 w.		......	......	......		......		Bayfield.
Mouth of Fish River...	47 15	291 25	1843·5	......	......	......		77 43	......	77·7		......		Graham.
S. Shore of St. John R.	47 17	291 32	1843·5	......	......	......		77 45	......	77·8		......		Graham.
Bourgeois House	46 31	291 37	1842·5	17 58 w.	......	18·0 w.		......	......	......		......		Boundary Survey.
Massardis River	46 31	291 38	1841·5	16 43 w.	0 05 w.	16·8 w.		......	......	......		......		Boundary Survey.
Madawaska River......	47 22	291 41	1843·5	......	......	......		77 48	......	77·8	77·8	......	13·33	Graham.
			1847·5	......	......	......		77 45	......	77·8		13·33		Keely.
Lake [illegible]	47 12	291 46	1842·5	17 53 w.	......	17·9 w.		......	......	......		......		Boundary Survey.
Mouth of Green River	47 19	291 50	1843·5	18 06 w.	0 05 E.	18·0 w.		......	......	......		......		Boundary Survey.
Mouth of Grand River	47 11	292 03	1844·5	......	......	......		77 39	......	77·7	77·6	......	13·53	Graham.
			1847·5	......	......	......		77 36	......	77·6		13·53		Keely.
Fort Fairfield	46 46	292 10	1841·5	17 27 w.	0 05 w.	17·5 w.		......	......	......		......		Boundary Survey.
St. Nicholas Harbour..	49 19	292 12	1830·5	19 57 w.	1 00 w.	21·0 w.		......	......	......		......		Bayfield.
N. Shore of St. John's	47 04	292 13	1843·5	......	......	......		77 31	......	77·5		......		Graham.
Peconk Hill	46 59	292 13	1841·5	17 43 w.	0 05 w.	17·8 w.		77 32	......	77·5		......		Graham.
Aroostook Hill	46 47	292 13	1841·5	17 28 w.	0 05 w.	17·6 w.		77 24	......	77·4		......		Graham.
Blue Hill	46 38	292 13	1841·5	17 15 w.	0 05 w.	17·3 w.		77 18	......	77·3		......		Boundary Survey.
Parks Hill...............	46 07	292 13	1841·5	16 09 w.	0 05 w.	16·2 w.		77 02	......	77·0		......		Graham.
Near River St. Croix...	45 57	292 13	1840·5	16 00 w.	0 10 w.	16·2 w.		76 57	......	77·0		......		Graham.
Grand Falls of St. John	47 03	292 15	1843·5	......	......	......		77 30	......	77·5	77·5	......		Graham.
			1847·5	......	......	......		77 30	......	77·5		......		Keely.
Rivière des Chutes ...	46 36	292 16	1847·5	......	......	......		77 11	......	77·2		13·23		Keely.
At sea....................	49 04	292 17	1842·5	21 37 w.	......	21·6 w.		79 24	......	79·4		......		Lefroy.
Woodstock	46 09	292 25	1847·5	......	......	......		77 05	......	77·1		13·22		Keely.
Pt. de Monts............	49 19	292 37	1830·5	20 13 w.	1 00 w.	21·2 w.		......	......	......		......		Bayfield.
Calais	45 11	292 43	1857·5	15 21 w.	1 15 E.	14·1 w.		76 24	......	76·4		13·69		U. S. Coast Survey.
[illegible]	[illegible] 38	292 49	1832·5	21 35 w.	0 50 w.	22·4 w.		......	......	......		......		Bayfield.
Chamcook	45 07	292 55	1859·5	17 36 w.	1 25 E.	16·2 w.		76 09	......	76·2		13·50		U. S. Coast Survey.
Cape Chatte	49 06	293 14	1830·5	21 27 w.	1 00 w.	22·5 w.		......	......	......		......		Bayfield.
Fredericton	45 55	293 17	1847·5	......	......	......		76 59	......	77·0		......		Keely.
At sea....................	49 36	293 21	1842·5	22 56 w.	......	22·9 w.		79 41	......	79·7		......		Lefroy.
Dalhousie Island	48 01	293 37	1839·5	20 15 w.	0 15 w.	20·5 w.		......	......	......		......		Bayfield.
Carleton Point	48 05	293 52	1838·5	20 23 w.	0 20 w.	20·7 w.		......	......	......		......		Bayfield.
St. John..................	45 14	293 57	1847·5	......	......	......		75 56	......	75·9		13·13		Keely.
Mount Lewis River ...	49 15	294 15	1828·5	22 00 w.	1 10 w.	23·2 w.		......	......	......		......		Bayfield.
Passebiac	48 01	294 25	1838·5	21 21 w.	0 20 w.	21·7 w.		......	......	......		......		Bayfield.
Vin Island, Miramichi	47 06	294 55	1837·5	19 46 w.	0 25 w.	20·2 w.		......	......	......		......		Bayfield.
Caraquette Island......	47 50	295 07	1838·5	21 30 w.	0 20 w.	21·8 w.		......	......	......		......		Bayfield.
Richibucto River	46 43	295 11	1839·5	19 50 w.	0 15 w.	20·1 w.		......	......	......		......		Bayfield.
Point Maquereau	48 12	295 13	1837·5	22 00 w.	0 25 w.	22·4 w.		......	......	......		......		Bayfield.
Kentville	45 12	295 14	1847·5	......	......	......		75 46	......	75·8		13·14		Keely.
Shipfrigan Harbour...	47 45	295 17	1838·5	21 43 w.	0 20 w.	22·1 w.		......	......	......		......		Bayfield.
Miscou Harbour	48 01	295 30	1838·5	20 35 w.	0 20 w.	20·9 w.		......	......	......		......		Bayfield.

ZONE II.—Lat. 45° to 50° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.	Inclination. Observed.	Inclination. Correction to Epoch 1842·5.	Inclination. Corrected.	Force in British units.	Observers.
	° ′	° ′		° ′	° ′	°	° ′		°		
Gaspe Basin	48 50	295 30	1832·0	22 04 w.	0 50 w.	22·9 w. } 22·7 w.	78 50	......	78·8	......	Bayfield.
			1846·0	22 49 w.	0 20 E.	22·5 w. }	......	......	......	......	Bayfield.
Cape Henry (Anticosti)	49 48	295 36	1830·0	24 22 w.	1 00 w.	25·4 w.	......	......	......	......	Bayfield.
[illegible] Island	46 15	295 37	1839·5	19 59 w.	0 15 w.	20·2 w.	......	.....	......	......	Bayfield.
Windsor	45 10	295 44	1847·5	......	.....	......	75 41	......	75·7	13·02	Keely.
Casumpeque	46 48	295 57	1845·5	21 10 w.	0 15 E.	20·9 w.	......	......	......	......	Bayfield.
Cape Tormentine	46 10	296 10	1840·5	20 00 w.	0 10 w.	20·2 w.	......	......	......	......	Bayfield.
Bedeque Harbour	46 24	296 12	1841·5	20 12 w.	0 05 w.	20·3 w.	......	......	......	......	Bayfield.
Carleton Head	46 15	296 17	1840·5	20 18 w.	0 10 w.	20·5 w.	......	......	......	......	Bayfield.
Richmond Bay	46 34	296 17	1845·5	21 00 w.	0 15 E.	20·8 w.	......	......	......	......	Bayfield.
Pugwash Harbour	45 53	296 19	1840·5	19 40 w.	0 10 w.	19·8 w.	......	......	......	......	Bayfield.
Wallace Harbour	45 49	296 34	1840·5	19 50 w.	0 10 w.	20·0 w.	......	......	......	......	Bayfield.
Cape T[illegible]	46 30	296 40	1845·5	21 41 w.	0 15 E.	21·4 w.	......	......	......	......	Bayfield.
Charlotte Town	46 14	296 52	1842·5	21 03 w.	......	21·1 w.	......	......	......	......	Bayfield.
Pictou Harbour	45 42	297 20	1841·5	20 19 w.	0 05 w.	20·4 w.	......	......	......	......	Bayfield.
George Town	46 11	297 27	1843·5	21 58 w.	0 05 E.	21·9 w.	......	......	......	......	Bayfield.
Merigomish Harbour	45 38	297 33	1842·5	20 15 w.	......	20·3 w.	......	......	......	......	Bayfield.
At sea	49 34	298 07	1842·5	27 23 w.	......	27·4 w.	......	......	......	......	Lefroy.
Amherst Harbour	47 15	298 10	1833·5	22 36 w.	0 45 w.	23·4 w.	......	......	......	......	Bayfield.
E. Point of Anticosti	49 08	298 18	1830·5	25 19 w.	1 00 w.	26·3 w.	......	......	......	......	Bayfield.
Bryon Island	47 48	298 34	1835·5	23 30 w.	0 35 w.	24·1 w.	......	......	......	......	Bayfield.
At sea	49 26	298 40	1842·5	27 48 w.	......	27·8 w.	79 12	......	79·2	......	Lefroy.
Isle Madame	45 28	298 57	1862·5	......	......	......	75 31	......	75·5	......	Shadwell.
[illegible]	[illegible]	299 04	1848·5	21 05 w.	0 30 E.	20·6 w.	......	......	......	......	Keely.
[illegible]	[illegible]	299 05	1848·5	22 30 w.	0 30 E.	22·0 w.	......	......	......	......	Keely.
[illegible]	[illegible]	299 37	1848·5	23 41 w.	0 30 E.	23·2 w.	......	......	......	......	Keely.
At sea	48 05	299 40	1842·5	26 57 w.	......	27·0 w.	78 29	......	78·5	......	Lefroy.
At sea	49 11	299 47	1842·5	28 16 w.	......	28·3 w.	......	......	......	......	Lefroy.
Cape Breton	46 16	299 52	1862·5	......	......	......	76 03	......	......	......	Shadwell.
Louisburg	45 53	300 00	1862·5	......	......	......	76 00	......	......	......	Shadwell.
At sea	47 18	300 15	1842·5	25 34 w.	......	25·6 w.	78 06	......	78·1	......	Lefroy.
Cod Roy Island	47 53	300 35	1835·5	25 00 w.	0 35 w.	25·6 w.	......	......	......	......	Bayfield.
At sea	46 11	304 29	1842·5	25 39 w.	......	25·7 w.	77 03	......	77·1	......	Lefroy.
At sea	46 13	304 53	1842·5	26 32 w.	......	26·5 w.	......	......	......	......	Lefroy.
At sea	45 52	306 49	1842·5	28 29 w.	......	28·5 w.	76 09	......	76·2	......	Lefroy.
St. John's Harbour	47 34	307 18	1844·5	29 36 w.	0 10 E.	29·4 w.	......	......	......	......	Bayfield.
At sea	45 12	309 48	1842·5	26 49 w.	......	26·8 w.	76 07	......	76·1	......	Lefroy.
At sea	46 09	323 37	1842·5	30 38 w.	......	30·6 w.	74 21	......	74·3	......	Lefroy.
At sea	48 11	324 30	1842·5	31 31 w.	......	31·5 w.	74 59	......	75·0	......	Lefroy.
At sea	47 06	325 40	1842·5	32 21 w.	......	32·4 w.	74 23	......	74·4	......	Lefroy.
At sea	46 41	326 36	1842·5	30 47 w.	......	30·8 w.	74 00	......	74·0	......	Lefroy.
At sea	47 21	330 56	1842·5	30 49 w.	......	30·8 w.	73 27	......	73·4	......	Lefroy.
At sea	45 35	332 25	1830·5	......	......	......	70 47	......	70·8	......	Erman.
At sea	45 52	333 32	1830·5	27 58 w.	......	28·0 w.	......	......	......	......	Erman.
At sea	46 53	334 07	1841·5	29 40 w.	......	29·7 w.	......	......	......	......	Barnett.
At sea	49 55	335 00	1846·5	......	......	......	72 32	......	72·5	......	Moore.
At sea	46 20	335 05	1830·5	28 23 w.	......	28·4 w.	......	......	......	......	Erman.
At sea	47 20	335 09	1842·5	31 07 w.	......	31·1 w.	72 27	......	72·5	......	Lefroy.
At sea	46 46	335 41	1830·5	......	......	......	70 07	......	70·1	10·99	Erman.
At sea	46 49	336 05	1841·5	30 04 w.	......	30·1 w.	......	......	......	......	Barnett.
At sea	45 45	336 26	1839·5	25 30 w.	......	25·5 w.	......	......	......	......	Bérard.
At sea	47 33	336 56	1842·5	31 17 w.	......	31·3 w.	72 08	......	72·1	......	Lefroy.
At sea	46 43	338 23	1839·5	27 00 w.	......	27·0 w.	......	......	......	......	Bérard.
At sea	46 53	338 25	1841·5	30 51 w.	......	30·9 w.	......	......	......	......	Barnett.
At sea	47 03	339 07	1830·5	27 54 w.	......	27·9 w.	......	......	......	......	Erman.
At sea	47 37	339 46	1841·5	30 30 w.	......	30·5 w.	......	......	......	......	Barnett.
At sea	48 02	340 55	1842·5	30 51 w.	......	30·9 w.	71 30	......	71·5	......	Lefroy.
At sea	47 55	342 25	1841·5	28 23 w.	......	28·4 w.	......	......	......	......	Barnett.
At sea	45 27	342 53	1839·0	......	......	......	69 30	......	69·5	......	Sulivan.
At sea	48 11	343 18	1841·5	29 26 w.	......	29·4 w.	......	......	......	......	Barnett.
At sea	49 17	343 31	1846·5	......	......	......	70 47	......	70·8	......	Moore.
At sea	49 16	343 51	1846·5	32 01 w.	......	32·0 w.	......	......	......	......	Moore.

ZONE II.—Lat. 45° to 50° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.		Inclination. Observed.	Inclination. Correction to Epoch 1842·5.	Inclination. Corrected.		Force in British units.		Observers.
	° ′	° ′		° ′	° ′	°		° ′	′	°				
At sea	47 47	343 58	1830·5	......	......	......		70 04	......	70·1		10·53		Erman.
At sea	48 18	344 23	1842	29 29 w.	......	29·5 w.		70 45	......	70·8		......		Lefroy.
At sea	47 45	344 24	1830	......	......	......		70 07	......	70·1		10·55		Erman.
At sea	47 56	345 03	1830	26 18 w.	......	26·3 w.		......	......	......		......		Erman.
At sea	49 17	345 31	1846·5	......	......	......		70 55	......	70·9		......		Moore.
At sea	48 34	346 00	1841	28 37 w.	......	28·6 w.		......	......	......		......		Barnett.
At sea	47 07	346 52	1839	......	......	......		68 52	......	68·9		......		Sulivan.
At sea	48 13	347 07	1830	......	......	......		69 30	......	69·5		10·51		Erman.
At sea	48 27	348 32	1830	26 06 w.	......	26·1 w.		......	......	......		......		Erman.
At sea	48 48	349 28	1842	27 44 w.	......	27·7 w.		69 45	......	69·7		......		Lefroy.
At sea	49 25	350 15	1846	27 46 w.	......	27·8 w.		......	......	......		......		Moore.
At sea	48 57	350 28	1830	25 58 w.	......	26·0 w.		......	......	......		......		Erman.
At sea	47 47	350 42	1840	......	......	......		......	......	......		10·55		Ross.
At sea	46 18	351 54	1839	24 14 w.	......	24·2 w.		......	......	......		......		Du Petit Thouars.
At sea	46 38	351 54	1842	27 10 w.	......	27·2 w.		......	......	......		......		Johenne.
At sea	49 16	351 57	1830	......	......	......		69 15	......	69·3		10·59		Erman.
At sea	49 22	352 22	1846	......	......	......		69 09	......	69·2		......		Moore.
At sea	49 11	352 22	1842	26 16 w.	......	26·3 w.		69 19	......	69·3		......		Lefroy.
At sea	49 37	354 55	1846	......	......	......		68 34	......	68·6		......		Moore.
At sea	48 09	355 02	1839	24 03 w.	......	24·1 w.		......	......	......		......		Du Petit Thouars.
Brest	48 24	355 30	1834	......	......	......	°	68 20	−20	68·0	°	10·32		Duperrey.
			1837	24 58 w.	0 28 E.	24·5 w.	24·5 w.	......	......	......	67·8	......	10·22	[illegible]
			1869	21 01 w.	3 21 w.	24·4 w.		66 26	+72	67·6		10·12		Perry.
At sea	49 58	356 27	1842·5	25 22 w.	......	25·4 w.		68 46	......	68·8		......		Lefroy.
Vannes	47 40	357 14	1869·0	20 14 w.	3 21 w.	23·6 w.		65 47	+72	67·0		10·08		Perry.
Cherbourg	49 39	358 22	1836·5	23 32 w.	0 46 E.	22·8 w.		68 35	−16	68·3	68·3	10·34	10·35	Lottin.
			1840 0	......	......	......		68 23	− 7	68·3		10·36		Gaimard.
Nantes	47 12	358 27	1842·5	22 51 w.	......	22·9 w.		66 36	......	66·6		10·19		Lamont.
Laval	48 04	359 13	1869·0	19 05 w.	3 22 w.	22·5 w.		65 48	+72	67·0		10·07		Perry.
Angers	47 28	359 26	1842·5	22 09 w.	......	22·2 w.	22·3 w.	66 36	......	66·6	66·5	10·20	10·11	Lamont.
			1869·0	19 06 w.	3 21 w.	22·5 w.		65 08	+72	66·3		10 02		Perry.

ZONE III.—LATITUDE 50° TO 55° N.

To this Zone belong the Stations (151 in number) comprised between the Latitudes of 50° N. and 55° N., printed in the Philosophical Transactions for 1870, Art. XIV. It has not been deemed necessary to reprint those stations here, as they admit of easy reference being made to them.

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ZONE III.—Lat. 50° to 55° N.

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Corr. to Epoch 1842·5.	Declination. Corrected.	Declination. Mean.	Inclination. Observed.	Inclination. Corr. to Epoch 1842·5.	Inclination. Corrected.	Inclination. Mean.	Force in British units. Observed.	Force. Corr. to Epoch 1842·5.	Force. Corrected.	Force. Mean.	Observers.
	° ′	° ′		° ′	° ′	°		° ′	′	°						
At sea	50 42	0 35	1840·0	......	......	......		68 29	......	68·5		10·17	......	10·17		Ross.
Douai	50 22	1 35	1839·0	18 05 w.	3 21 w.	21·4 w.		66 47	+72	68·0		10·13	......	10·13		Perry.
Lille	50 39	1 36	1856·0	......	......	......		67 31	−34	68·1		......	......	......		Mahmoud.
Boulogne	50 55	1 37	1839·0	18 13 w.	3 21 w.	21·6 w.		67 07	+72	68·3		10·15	......	10·15		Perry.
Calais	50 58	1 51	1856·0	......	......	......		67 53	+34	68·6		......	......	......		Mahmoud.
Dunkirk	51 02	2 22	1835·5	......	......	......	22·1 w.	68 55	−21	68·5	68·6	10·35	......	10·36	10·33	[illegible]
			1858·0	20 07 w.	1 56 w.	22·1 w.		67 57	+39	68·6		10·52	−·02	10·30		Lamont.
Arras	50 18	2 16	1858·0	......	......	......		67 23	+40	68·1		10·27	−·02	10·25		Lamont.
Ostend	51 14	2 55	1856·0	......	......	......		68 03	+31	68·6		......	......	......		Mahmoud.
Courtrai	50 50	3 16	1856·0	......	......	......		67 40	+34	68·2		......	......	......		Mahmoud.
Valenciennes	50 21	3 31	1856·0	......	......	......		67 23	+31	68·0		......	......	......		Mahmoud.
Ghent	51 03	3 43	1856·0	......	......	......	21·5 w.	67 50	+34	68·4	68·5	......	......	......	10·28	Mahmoud.
			1858·0	19 31 w.	1 56 w.	21·5 w.		68 00	+39	68·7		10·30	−·02	10·28		Lamont.
Mons	50 30	3 58	1856·0	......	......	......		67 23	+34	68·0		......	......	......		Mahmoud.
The Hague	52 04	4 18	1856·0	......	......	......		68 19	+31	68·9		......	......	......		Mahmoud.
Brussels	50 51	4 22	1838·5	......	......	......		68 28	−10	68·3	68·2	10·27	......	10·27	10·28	Forbes.
			1842·5	21 31 w.	......	21·5 w.		68 13	......	68·2		10·28	......	10·28		Quetelet.
Antwerp	51 13	4 21	1856·0	......	......	......		67 53	+34	68·5		......	......	......		Mahmoud.
Rotterdam	51 55	4 29	1838·5	......	......	......		68 49	−10	68·7	68·7	10·17	......	10·17	10·17	Fox.
			1856·0	......	......	......		68 12	+34	68·8		......	......	......		Mahmoud.
Leyden	52 09	4 29	1856·0	......	......	......		68 16	+34	68·8	68·9	......	......	......	10·31	Mahmoud.
			1858·0	19 15 w.	1 56 w.	21·2 w.		68 22	+39	69·0		10·33	−·02	10·31		Lamont.
Malines	51 02	4 29	1858·0	19 13 w.	1 56 w.	21·2 w.		67 29	+39	68·3		10·28	−·02	10·26		Lamont.
Amsterdam	52 23	4 53	1856·0	......	......	......		68 24	+31	69·0		......	......	......		Mahmoud.
Utrecht	52 06	5 07	1858·0	18 18 w.	1 56 w.	20·7 w.		68 12	+39	68·9		10·32	−·02	10·30		Lamont.
Liége	50 37	5 35	1839·0	......	......	......		68 05	−9	67·9		10·35	......	10·35		Quetelet.
Arnheim	52 00	5 50	1838·0	......	......	......		68 45	−11	68·6		......	......	......		Fox.
Aix La Chapelle	50 47	6 04	1858·0	19 15 w.	1 56 w.	21·2 w.		67 27	+39	68·1		10·26	−·02	10·24		Lamont.
Cologne	50 57	6 46	1838·0	......	......	......		67 54	−11	67·7		10·05	......	10·05		Fox.
Oberhausen	51 29	6 51	1858·0	17 56 w.	1 56 w.	19·9 w.		67 50	+39	68·3		10·23	−·02	10·21		Lamont.
Bonn	50 44	7 06	1838·5	......	......	......	19·6 w.	67 51	−10	67·7	67·8	10·20	......	10·20	10·18	Forbes.
			1858·0	17 38 w.	1 56 w.	19·6 w.		67 12	+39	67·9		10·18	−·02	10·16		Lamont.
			1859·5	......	......	......		67 09	+42	67·9		......	......	......		Fox.
Emden	53 22	7 12	1858·0	18 09 w.	1 56 w.	20·1 w.		68 52	+39	69·5		10·38	−·02	10·36		Lamont.
Münster	51 58	7 38	1858·0	17 29 w.	1 56 w.	19·4 w.		67 53	+39	68·5		10·29	−·02	10·27		Lamont.
Marburg	50 09	8 46	1850·0	17 40 w.	0 56 w.	18·6 w.		67 18	+19	67·6		10·23	......	10·23		Lamont.
Flensburg	54 47	9 26	1858·0	......	......	......		69 21	+39	70·0		10·58	−·02	10·56		Lamont.
Cassel	51 20	9 30	1858·0	16 23 w.	1 56 w.	18·3 w.		67 11	+39	67·8		10·22	−·02	10·20		Lamont.
Fulda	50 34	9 30	1850·0	17 16 w.	0 56 w.	18·2 w.		68 13	+19	68·5		......	......	......		Lamont.
Göttingen	51 32	9 56	1842·5	17 52 w.	......	17·9 w.		67 40	......	67·7		......	......	......		Observatory.
Altona	53 33	9 57	1839·5	......	......	......		69 01	−7	68·9		10·39	......	10·39		Hansteen.
Kiel	54 20	10 09	1840·0	......	......	......		69 28	−6	69·4		10·41	......	10·41		Hansteen.
Schweinfurt	50 03	10 14	1850·0	16 51 w.	0 56 w.	17·8 w.		66 32	+19	65·9		10·17	−·02	10·15		Lamont.
Gotha	50 57	10 44	1858·0	15 38 w.	1 56 w.	17·6 w.		66 50	+39	67·5		10·19	−·02	10·17		Lamont.
Culmbach	50 06	11 29	1850·0	16 15 w.	0 56 w.	17·2 w.		66 25	+19	66·7		10·11	−·01	10·10		Lamont.
Lichtenfels	50 09	11 31	1850·0	16 30 w.	0 56 w.	17·4 w.		66 29	+19	66·8		10·14	−·01	10·13		Lamont.
Halle	51 30	11 58	1867·5	......	......	......		66 31	+63	67·6		......	......	......		Kämtz, L. F.
Wunsiedel	50 02	12 01	1850·0	15 53 w.	0 56 w.	16·8 w.		66 27	+19	66·8		10·17	−·01	10·16		Lamont.
Rostock	54 05	12 09	1858·0	15 17 w.	1 56 w.	17·2 w.		68 39	+39	69·3		10·39	−·02	10·37		Lamont.
Franzensbad	50 07	12 20	1850·0	......	......	......		66 13	+19	66·5		10·08	−·01	10·07		Kreil.
Leipzig	51 20	12 22	1825·0	......	......	......	16·7 w.	68 08	−44	67·4	67·4	......	......	......	10·13	Keilhau.
			1850·0	15 40 w.	0 56 w.	16·6 w.		67 05	+19	67·4		......	......	......		D'Arrest.
			1858·0	14 45 w.	1 56 w.	16·7 w.		66 46	+39	67·4		10·15	−·02	10·13		Lamont.
			1867·5	......	......	......		66 16	+63	67·4		......	......	......		Kämtz, L. F.
Carlsbad	50 14	12 53	1838·5	......	......	......	16·4 w.	66 41	−12	66·5	66·5	10·12	......	10·12	10·10	Forbes.
			1850·0	15 36 w.	0 50 w.	16·4 w.		66 10	+17	66·5		10·08	......	10·08		Kreil.
Potsdam	52 23	13 05	1828·0	17 33 w.	1 04 e.	16·5 w.		68 31	−48	67·7		......	......	......		Erman.
Chiesch	50 06	13 16	1850·0	15 24 w.	0 50 w.	16·2 w.		65 51	+17	66·1		9·99	......	9·99		Kreil.
Berlin	52 32	13 24	1842·5	16 12 w.	......	16·2 w.		67 53	......	67·9		10·03	......	10·03		Erman.
Komotau	50 27	13 25	1850·0	15 14 w.	0 50 w.	16·1 w.		66 10	+17	66·5		9·98	......	9·98		Kreil.
Dresden	51 03	13 44	1825·5	......	......	......		67 41	−32	67·2	67·1	10·38	......	10·38	10·38	Keilhau.
			1867·5	......	......	......		66 15	+50	67·1		......	......	......		Kämtz, L. F.

ZONE III.—Lat. 50° to 55° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.		Inclination. Observed.	Inclination. Cor. to Epoch 1842·5.	Inclination. Corrected.		Force in British units. Observed.	Force. Cor. to Epoch 1842·5.	Force. Corrected.		Observers.
	° ′	° ′		° ′	° ′	°	°	° ′	′	°	°					
Toplitz	50 39	13 47	1826·5	......	......	......	15·8 w.	67 12	−53	66·3	66·5	10·35	......	10·35	10·19	Keilhau.
			1850·0	15 00 w.	0 50 w.	15·8 w.		66 25	+15	66·7		10·04	......	10·04		Kreil.
Bodenbach	50 46	14 12	1850·0	14 55 w.	0 50 w.	15·8 w.		66 32	+15	66·8		10·12	......	10·12		Kreil.
Prague	50 05	14 27	1842·5	15 28 w.	......	15·5 w.		66 13	......	66·2		10·14	......	10·14		Kreil.
Leipa	50 41	14 33	1850·0	......	......	......		66 18	+15	66·6		10·06	......	10·06		Kreil.
[illegible]	53 25	14 34	1858·0	13 32 w.	1 41 w.	15·2 w.		67 52	+31	68·4		10·25	−·02	10·23		Lamont.
Gorlitz	51 09	14 58	1858·0	13 34 w.	1 41 w.	15·3 w.		66 30	+31	67 0		10·14	−·02	10·12		Lamont.
Reichenberg	50 46	15 04	1850·0	......	......	......		66 23	+15	66·6		10·06	......	10·06		Kreil.
Landsberg	52 44	15 15	1858·0	13 17 w.	1 41 w.	15·0 w.		67 27	+31	68·0		10·22	−·02	10·20		Lamont.
Chlumetz	50 09	15 27	1850·0	14 08 w.	0 50 w.	15·0 w.		65 47	+15	66·0		9·96	......	9·96		Kreil.
Posen	52 25	15 34	1858·0	12 16 w.	1 41 w.	14·0 w.		67 05	+31	67·6		10·19	−·02	10·17		Lamont.
Hohenelbe	50 37	15 36	1850·0	......	......	......		66 12	+15	66·5		10 05	......	10·05		Kreil.
Nachod	50 25	16 08	1850·0	......	......	......		65 50	+15	66·1		9·94	......	9·94		Kreil.
Kwasnei	50 11	16 16	1850·0	13 50 w.	0 48 w.	14·6 w.		65 38	+15	65·9		9·97	......	9·97		Kreil.
Senftenberg	50 05	16 27	1850·0	13 32 w.	0 48 w.	14·3 w.		65 43	+15	66·0		10·04	......	10·04		Kreil.
Breslau	51 07	17 02	1858·0	12 12 w.	1 39 w.	13·9 w.		66 08	+31	66·7		10 09	−·02	10 07		Lamont.
Bromberg	53 08	18 01	1858·0	11 19 w.	1 39 w.	13·0 w.		67 20	+23	67·7		10·25	−·02	10·23		Lamont.
Dirschau	54 04	18 38	1858·0	10 36 w.	1 39 w.	12·3 w.		68 18	+23	68·7		10·35	−·02	10·33		Lamont.
Cracow	50 04	19 57	1850·0	11 36 w.	0 48 w.	12·4 w.	12·4 w.	65 22	+11	65·6	65·6	10·09	......	10·09	10·09	Kreil.
			1867·5	......	......	......		64 51	+37	65·5		......	......	......		Kämtz, L. F.
Königsberg	54 43	20 30	1828·5	13 21 w.	1 30 E.	11·9 w.	11·9 w.	......	......	......	69·2	......	......	......	10·29	Erman.
			1829·5	......	......	......		69 26	−20	69·1		......	......	......		Humboldt.
			1858·0	10 12 w.	1 39 w.	11·9 w.		68 49	+23	69·2		10·31	−·02	10·29		Lamont.
Tarnow	50 01	21 01	1850·0	11 12 w.	0 48 w.	12·0 w.		65 24	+11	65·6		10·20	......	10·20		Kreil.
Warsaw	52 13	21 02	1867·5	......	......	......		66 37	+37	67·2		......	......	......		Kämtz, L. F.
Rzeszow	50 03	22 00	1850·0	10 24 w.	0 48 w.	11·2 w.		65 03	+11	65·2		10·13	......	10·13		Kreil.
Nisko	50 34	22 09	1850·0	10 08 w.	0 48 w.	10·9 w.		65 16	+11	65·5		10·10	......	10·10		Kreil.
Rawa Ruska	50 17	23 39	1850·0	9 19 w.	0 48 w.	10·1 w.		65 08	+11	65·3		10·08	......	10·08		Kreil.
Grodno	53 41	23 50	1867·5	......	......	......		67 11	+37	67·8		......	......	......		Kämtz, L. F.
Brody	50 05	25 11	1850·0	9 03 w.	0 48 w.	9·9 w.		64 44	+11	64·9		10·14	......	10·14		Kreil.
Woroncje	51 40	39 20	1829·0	......	......	......		65 12	−20	64·9		......	......	......		Humboldt.
Wasiliew Maidan	54 51	44 48	1830·0	1 34 E.	0 26 E.	2·0 E.		67 39	−11	67·5		10·93	−·04	10·89		Hansteen.
Pensa	53 11	44 59	1830·5	0 06 E.	0 27 E.	0·6 E.	0·6 E.	66 02	−10	65·9	66·1	10·60	−·04	10·56	10·56	Hansteen.
			1850·0	......	......	......		66 10	+ 6	66·3		......	......	......		Sawalief.
Saransk	54 11	45 13	1830·5	0 24 w.	0 27 E.	0·1 E.		67 02	−10	66·9		10·65	−·04	10·61		Hansteen.
Tschumakowsk	52 30	45 15	1830·5	0 51 E.	0 27 E.	1·3 E.		65 23	−10	65·2		10·57	−·04	10·53		Hansteen.
Nowokutlina	53 40	45 15	1830·5	0 23 E.	0 27 E.	0·8 E.		......	......	......		......	......	......		Hansteen.
Kamyschin	50 06	45 24	1830·5	......	......	......		63 46	− 9	63·6	63·9	10·40	−·04	10·36	10·36	Hansteen.
			1850·0	......	......	......		64 03	+ 6	64·2		......	......	......		Sawalief.
Saratow	51 32	46 04	1829·5	......	......	......	0·3 E.	64 41	− 9	64·5	64·6	......	......	......	10·49	Humboldt.
			1830·5	0 07 w.	0 27 E.	0·3 E.		64 40	− 9	64·6		10·52	−·03	10·49		Hansteen.
			1850·5	......	......	......		64 49	+ 6	64·9		......	......	......		Sawalief.
Chewalinsk	52 30	48 07	1850·5	......	......	......		65 54	+ 6	66·0		......	......	......		Sawalief.
Simbirsk	50 19	48 25	1850·5	......	......	......		67 05	+ 6	67·2		......	......	......		Sawalief.
Samara	53 10	50 05	1850·5	......	......	......		66 24	+ 6	66·5	66·5	......	[illegible]	[illegible]	[illegible]	[illegible]
			1869·5	6 51 E.	?	......		66 13	?	......		10·80	[illegible]	[illegible]		[illegible]
Sergiewsk	53 55	51 14	1850·5	......	......	......		67 48	+ 5	67·9		11·05	[illegible]	[illegible]		[illegible]
Uralsk	51 12	51 24	1829·5	......	......	......	3·0 E.	64 19	− 8	64·2	64·2	......	......	......	10·83	Humboldt.
			1830·5	2 32 E.	0 27 E.	3·0 E.		64 15	− 8	64·1		10·85	−·02	10 83		Hansteen.
Irtek	51 31	52 37	1830·5	2 22 E.	0 28 E.	2·8 E.		64 29	− 7	64·4		10·81	−·02	10·79		Hansteen.
Osernaia	51 36	53 57	1830·0	3 05 E.	0 28 E.	3·6 E.		......	......	......		......	......	......		Hansteen.
Detskaia	51 07	55 01	1830·0	......	......	......		64 42	− 4	64·6		10·80	−·02	10·78		Hansteen.
Orenburg	51 46	55 06	1829·5	......	......	......	3·9 E.	64 41	− 2	64·7	64·8	10·92	−·01	10·91	10·91	Humboldt.
			1830·5	3 18 E.	0 32 E.	3·8 E.		64 48	− 2	64·8		10·92	−·01	10 91		Hansteen.
			1832·5	3 27 E.	0 27 E.	3·9 E.		64 47	− 1	64·8		......	......	......		Federow.
Melous	53 04	55 49	1829·5	3 11 E.	0 32 E.	3·7 E.		66 14	− 1	66·2		11·05	−·01	11·04		Hansteen.
Ufa	54 43	55 56	1830·0	......	......	......		67 37	− 1	67·6		11·20	−·01	11·19		Hansteen.
Tolbasi	54 05	55 57	1830·0	......	......	......		67 13	− 1	67·2		11·13	−·01	11·12		Hansteen.
Miask	54 59	60 06	1829·5	......	......	......		67 40	+ 2	67·7		......	......	......		Humboldt.
Koielskaia	54 43	60 54	1830·0	......	......	......		67 47	+ 2	67·8		11·39	......	11·39		Hansteen.
Troisk	54 05	61 35	1829·0	6 41 E.	0 35 E.	7·3 E.	7·3 E.	67 21	+ 3	67·4	67·4	11·41	......	11·41	11·41	Hansteen.
			1829·5	......	......	......		67 14	+ 3	67·3		......	......	......		Humboldt.
Kotscherdinsk	54 21	64 44	1828·5	7 07 E.	0 36 E.	7·7 E.		67 41	+ 6	67·8		11·47	+·02	11·49		Hansteen.

ZONE III.—Lat. 50° to 55° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Correction to Epoch 1842·5.	Corrected.		Inclination. Observed.	Corr. to Epoch 1842·5.	Corrected.		Force in British units. Observed.	Corr. to Epoch 1842·5.	Corrected.		Observers.
	° ′	° ′		° ′	° ′	°		° ′	′	°						
Swerinogolowsk	51 21	65 00	1831·0	7 35 E.	0 37 E.	8·2 E.		67 19	+ 6	67·9		......	......	......		Fedorow.
[illegible]	51 30	66 15	1829·5	6 59 E.	0 37 E.	7·6 E.		67 48	+ 7	67·9		11·52	·02	11·54		Hansteen.
[illegible]	51 39	67 53	1829·5	7 47 E.	0 38 E.	8·4 E.		68 08	+ 9	68·3		11·74	·03	11·77		Hansteen.
St. Peter's	51 52	69 06	1829·5	......	......	......	8·9 E.	68 18	+ 9	68·5	68·6	......	......	......	11·76	Hansteen.
			1829·5	8 36 E.	0 38 E.	8·9 E.		68 26	+ 9	68·6		11·73	·03	11·76		Hansteen.
Lebiasje	51 58	71 09	1829·5	......	......	......		68 17	+11	69·0		11·85	·03	11·88		Hansteen.
Omsk	54 59	73 21	1829·5	......	......	......	9·6 E.	68 54	+13	69·1	69·2	......	......	......	11·98	Hansteen.
			1829·5	8 49 E.	0 39 E.	9·5 E.		68 54	+13	69·1		11·95	·04	11·99		Hansteen.
			1830·0	......	......	......		68 58	+13	69·2		......	......	......		Fuss, G. von.
			1831·0	9 22 E.	0 14 E.	9·6 E.		68 59	+10	69·2		......	......	......		Federow.
			1867·5	11 36 E.	?	?		69 12	?	?		12·02	−·7	11·97		Fritsche.
Pokrowsk	51 29	74 00	1828·5	8 44 E.	0 37 E.	9·4 E.	9·4 E.	......	......	......	69·9	......	......	......	12·21	Hansteen.
			1829·5	......	......	......		69 39	+13	69·9		12·17	·04	12·21		Erman.
Isylbasch'koi	54 29	74 20	1828·5	......	......	......		68 30	+13	68·7		12·03	·04	12·07		Hansteen.
Schelesinskaia	53 32	75 13	1828·5	8 16 E.	0 35 E.	8·9 E.		67 47	+14	68·0		12·15	·04	12·19		Hansteen.
Posch[illegible]	52 38	76 51	1828·5	7 25 E.	0 35 E.	8·0 E.		......	......	......		......	......	......		Hansteen.
Prastai	52 16	77 23	1829·5	......	......	......		67 15	+17	67·5		11·90	·04	11·94		Hansteen.
Jamyschewsk............	51 50	77 26	1828·5	7 16 E.	0 35 E.	7·9 E.	8·0 E.	66 31	+17	66·8	66·7	11·94	·05	11·99	11·99	Hansteen.
			1831·5	7 45 E.	0 21 E.	8·1 E.		66 29	+10	66·7		......	......	......		Federow.
Semijarskoi	50 53	78 21	1828·5	5 56 E.	0 35 E.	6·5 E.		65 48	+19	66·1		11·90	·05	11·95		Hansteen.
Semipalatinsk	50 24	80 21	1828·5	6 45 E.	0 36 E.	7·3 E.		65 18	+20	65·6		11·88	·06	11·94		Hansteen.
Semiluskoi	50 23	81 14	1828·5	6 33 E.	0 35 E.	7·2 E.		65 14	+21	65·6		11·65	·06	11·71		Hansteen.
Smeinogorsk	51 09	82 25	1828·5	7 19 E.	0 36 E.	7·9 E.	7·9 E.	66 02	+23	66·4	66·5	12·02	·07	12·09	12·09	Hansteen.
			1829·5	......	......	......		66 06	+23	66·5		......	......	......		Hansteen.
Kolywan[illegible]	51 45	82 46	1829·5	......	......	......		66 46	+25	67·2		12·00	·07	12·07		Hansteen.
Bos[illegible]	52 30	83 20	1829·5	......	......	......		67 21	+25	67·8		12·12	·07	12·19		Hansteen.
Barnaul	53 20	83 57	1829·5	7 25 E.	0 35 E.	8·0 E.	8·0 E.	68 15	+27	68·7	68·7	12·27	·07	12·34	12·34	Hansteen.
			1829·5	......	......	......		68 10	+27	68·6		......	......	......		Hansteen.
Legostaiewa	54 25	84 11	1829·5	......	......	......		69 39	+27	70·0		12·35	·07	12·42		Hansteen.
Nishne Udinsk	54 55	99 02	1829·5	4 40 E.	0 22 E.	5·0 E.		70 36	+30	71·1		12·74	·10	12·84		Hansteen.
Karsan	51 31	100 03	1829·0	......	......	......		70 10	+30	70·7		12·65	·11	12·76		Erman.
Tunkinska	51 45	100 49	1832·5	2 56 E.	0 18 E.	3·2 E.		......	......	......		......	......	......		Fuss.
Kuitunskaia	54 15	101 21	1829·0	3 34 E.	0 18 E.	3·9 E.		70 23	+31	70·9		12·77	·11	12·88		Hansteen.
Sima	53 50	101 31	1829·5	......	......	......		69 32	+31	70·1	70·1	......	......	......		Erman.
			1867·5	3 35 E.	?	?		71 09	−62	70·1		......	......	......		Fritsche.
Salari'a	53 31	102 03	1829·0	......	......	......		69 15	+31	69·8	69·7	12·70	·11	12·81	12·75	Erman.
			1829·0	......	......	......		69 18	+31	69·8		12·58	·11	12·69		Hansteen.
			1867·0	......	......	......		70 36	−62	69·6		......	......	......		Fritsche.
Telminskoi............	52 31	103 10	1829·0	......	......	......		68 36	+32	69·1		12·58	·11	12·69		Hansteen.
Balagansk	53 40	103 11	1829·5	......	......	......		69 35	+32	70·1		12·71	·11	12·82		Hansteen.
Janalinskoi............	54 26	103 16	1829·5	2 44 E.	0 16 E.	3·0 E.		70 19	+33	70·9		12·72	·12	12·84		Hansteen.
Angara	53 21	103 23	1829·5	......	......	......		69 25	+33	70·0		12·81	+·12	12·93		Hansteen.
Irkutzk	52 17	104 20	1820·0	2 03 E.	?	?	1·9 E.	67 11	+59	68·2	68·7	......	......	......	12·7[illegible]	Wrangel.
			1829·5	......	......	......		68 13	+34	68·8		12·65	+·12	12·77		Due.
			1829·5	1 52 E.	0 14 E.	2·1 E.		68 07	+34	68·7		12·49	[illegible]	[illegible]		[illegible]
			1829·5	1 36 E.	0 14 E.	1·8 E.		68 12	+34	68·8		12·58	[illegible]	[illegible]		[illegible]
			1829·5	......	......	......		68 13	+34	68·8		12·66	[illegible]	[illegible]		[illegible]
			1830·5	1 25 E.	0 13 E.	1·6 E.		68 20	+31	68·9		12·51	+·12	12·63		Fuss.
			1868·0	2 42 E.	0 42 W.	2·0 E.		69 45	−62	68·7		12·66	?	?		Fritsche.
Listwinischnoi	51 54	104 30	1830·0	......	......	......		67 58	+34	68·5		12·52	+·12	12·64		Fuss.
Charazaiska	50 29	104 44	1830·5	2 27 E.	0 13 E.	2·7 E.		66 57	+34	67·5		12·31	+·12	12·43		Fuss.
Olsonsk	53 02	104 59	1829·5	......	......	......		68 44	+34	69·3		12·79	+·12	12·91		Erman.
Kadilnaia	52 00	104 59	1829·0	......	......	......		67 34	+34	68·1	68·2	12·45	+·12	12·57	12·62	Erman.
			1829·0	......	......	......		67 40	+34	68·2		12·56	+·12	12·68		Hansteen.
Tjumenowsk	54 15	105 20	1829·5	......	......	......		70 12	+34	70·8		12·75	+·12	12·87		Erman.
Ponomarsewsk	54 59	105 22	1829·5	......	......	......		70 23	+34	71·0		12·83	+·12	12·95		Due.
Chogotskaia	53 38	105 25	1829·5	......	......	......		68 49	+34	69·4		12·57	+·12	12·69		Due.
Munsursk	53 25	105 41	1829·5	1 18 E.	0 12 E.	1·5 E.		......	......	......		......	......	......		Erman.
Baikal	52 02	106 10	1829·0	1 03 E.	0 11 E.	1·2 E.	1·1 E.	......	......	......	68·5	......	......	......	13·22	Erman.
			1829·0	0 43 E.	0 11 E.	0·9 E.		67 58	+34	68·5		13·10	+·12	13·22		Hansteen.
Possolsk............	52 01	106 17	1832·5	......	......	......		68 02	+34	68·6		12·38	+·12	12·50		Fuss.
Stepnoi	52 10	106 20	1830·5	1 08 E.	0 11 E.	1·3 E.		68 11	+34	68·8		12·69	+·12	12·81		Fuss.

ZONE III.—Lat. 50° to 55° N. (continued).

Troizko Sawsk	50 21	106 28	1829·0	0 35 W.	0 11 E.	0·4 W.	0·1 E.	66 14	+35	66·8	66·9	12·41	+·12	12·53	12·59	Erman.
			1831·0	0 01 E.	0 10 E.	0·2 E.		66 24	+31	66·9		......	......	......		Fuss.
			1867·5	0 39 E.	0 21 W.	0·3 E.		67 48	−55	66·9		12·62	?	?		Fritsche.
Monachonowo	50 58	106 28	1829·0	0 31 E.	0 10 E.	0·7 E.	0·7 E.	66 57	+35	67·5		12·46	+·12	......	12·54	Erman.
			1829·0	......	......	......		66 49	+35			12·39	+·12	12·54		Hansteen.
Kolessowaia	52 07	106 32	1830·5	......	......	......		68 10	+34	68·7		12·71	?	?		Fuss.
Selenginsk	51 06	106 39	1829·0	0 16 E.	0 10 E.	0·4 E.	0·9 E.	66 51	+35	67·4	67·4	12·50	+·12	12·62	12·62	Hansteen.
			1832·5	1 13 E.	0 10 E.	1·4 E.		......	......	......		......	......	......		Fuss.
Tarakonowo	52 03	106 53	1829·0	......	......	......		68 22	+35	69·0		12·63	+·12	12·75		Erman.
Kurbinsk	52 05	106 53	1832·5	......	......	......		67 59	+33	68·5		12·47	+·12	12·59		Fuss.
Arsentschewa	51 17	106 55	1829·0	......	......	......	0·3 E.	67 34	+35	68·2	68·0	12·62	+·13	12·75	12·69	Hansteen.
			1829·0	0 10 E.	0 10 E.	0·3 E.		67 16	+35	67 9		12·50	+·13	12·63		Erman.
W. Udinsk	51 49	107 44	1829·0	......	......	......	0·6 E.	67 54	+35	68·5	68·5	12·32	+·14	12·46	12·48	Erman
			1829·0	......	......	......		67 53	+35	68·5		12·36	+·14	12·50		Hansteen.
			1832·5	0 24 E.	0 10 E.	0·6 E.		68 06	+26	68·5		......	......	......		Fuss.
			1868 0	0 01 E.	......	......		68 57	?	?		12·46	?	?		Fritsche.
[illegible]	52 57	108 24	1832·5	1 10 E.	0 10 E.	1·3 E.		......	......	......		......	......	......		Fuss.
[illegible]	51 15	110 34	1832·5	0 23 E.	0 10 E.	0·6 E.		......	......	......		......	......	......		Fuss.
Pogromnoi	52 30	111 03	1832·5	0 18 W.	0 10 E.	0·2 W.		68 08	+37	68·8		12·28	+·14	12·42		Fuss.
[illegible]	52 05	111 03	1832·5	......	......	......		67 59	+37	68·6		12·47	+·14	12·61		Fuss.
[illegible]	50 15	113 24	1832·5	......	......	......		66 40	+37	67·3		12·51	+·14	12·65		Fuss.
[illegible]	52 01	113 26	1832·5	1 13 W.	......	1·2 W.		67 43	+37	68·3		12·49	+·14	12·63		Fuss.
[illegible]	50 34	115 31	1832·5	2 14 W.	0 02 W.	2·3 W.		66 32	+37	67·2		12·36	+·14	12·50		Fuss.
[illegible] Town	51 56	116 30	1832·5	2 53 W.	0 02 W.	2·9 W.		67 12	+37	67·8		12 24	+·14	12·38		Fuss.
Altagan	50 20	117 12	1832·5	1 50 W.	0 03 W.	1·9 W.		......	......	......		......	......	......		Fuss.
Stretensk	52 15	117 39	1832·5	2 52 W.	0 04 W.	2·9 W.		67 39	+37	68·3		12·35	+·14	12·49		Fuss.
Zuruchaitu	50 23	119 02	1832 5	3 11 W.	0 04 W.	3·3 W.		66 13	+37	66·8		12·17	+·14	12·31		Fuss.
Gorbizkoi	53 06	119 08	1832·5	2 54 W.	0 04 W.	3·0 W.		68 22	+37	69·0		12·43	+·14	12·57		Fuss.
Nertchinsk Mine	51 19	119 36	1832·5	4 06 W.	0 04 W.	4·2 W.	4·0 W.	66 34	+38	67·2	67·2	12·10	+·14	12·24	12·24	Fuss.
			1842·5	3 50 W.	......	3·8 W.		67 09	......	67·2		......	......	......		Observatory.
			1869·5	......	......	......		67 57	?	?		......	......	......		Observatory.
Argunskoi	51 33	119 56	1832·5	3 44 W.	0 04 W.	3·8 W.		66 54	+38	67·5		12·39	+·14	12·53		Fuss.
Uruipina	52 47	120 03	1832·5	4 04 W.	0 04 W.	4·1 W.		67 53	+38	68·5		12·48	+·14	12·62		Fuss.
Liapina River	53 27	120 38	1832·5	3 27 W.	0 05 W.	3·5 W.		......	......	......		......	......	......		Fuss.
Ust Urowskoi	52 08	121 08	1832·5	2 57 W.	0 05 W.	3·0 W.		......	......	......		......	......	......		Fuss.
Schegdatschinskoi	53 15	121 20	1832·5	......	......	......		68 11	+39	68·8		12·42	+·14	12·56		Fuss.
Uststretensk	53 20	121 50	1832 5	4 21 W.	0 05 W.	4·4 W.		68 11	+39	68·8		12·40	+·14	12·54		Fuss.
Umutna River	53 20	123 05	1832·5	3 39 W.	0 06 W.	3·7 W.		......	......	......		......	......	......		Fuss.
Oldoi	53 30	123 23	1832·5	3 46 W.	0 06 W.	3·9 W.		......	......	......		......	......	......		Fuss.
Udsk	54 30	134 37	1830·5	5 00 W.	0 08 W.	5·1 W.		......	......	......		......	......	......		Kosmin.
Uda River	54 42	135 25	1830·5	5 07 W.	0 09 W.	5·3 W.		......	......	......		......	......	......		Kosmin.
Cape Dugandscha	54 37	136 45	1830·5	5 20 W.	0 09 W.	5·5 W.		......	......	......		......	......	......		Kosmin.
Great Shantar Island	55 00	138 04	1830·5	5 25 W.	0 10 W.	5·6 W.		......	......	......		......	......	......		Kosmin.
Natschika	53 07	157 25	1829·5	4 00 E.	0 14 W.	3·8 E.		64 05	+42	64·8		11·45	+·16	11·61		Erman.
At sea	51 05	158 01	1849·5	4 56 E.	......	4·9 E.		......	......	......		......	......	......		Kellett.
At sea	50 05	158 39	1848·5	2 19 E.	......	2·3 E.		......	......	......		......	......	......		Kellett.
Petropaulowsk	53 00	158 40	1825·5	1 13 E.	0 14 W.	4·0 E.	3·5 E.	61 02	+43	64·8	64·7	......	......	......	11·41	Beechey.
			1827·5	3 43 E.	0 14 W.	3·5 E.		61 07	+43	64·8		......	......	......		Lütke.
			1829·5	4 04 E.	0 14 W.	3·8 E.		63 50	+43	64·6		11·25	+·16	11·41		Erman.
			1849·5	2 37 E.	0 07 E.	2·7 E.		......	......	......		......	......	......		Kellett.
At sea	52 23	158 47	1848·5	2 57 E.	......	3·0 E.		......	......	......		......	......	......		Kellett.
At sea	52 51	160 05	1850·0	3 37 E.	......	3·6 E.		......	......	......		......	......	......		Kellett.
At sea	52 41	160 50	1849·5	4 15 E.	......	4·3 E.		......	......	......		......	......	......		Kellett.
At sea	52 56	160 51	1828·0	4 17 E.	......	4·3 E.		......	......	......		......	......	......		Lütke.
At sea	52 14	161 30	1850·0	6 30 E.	......	6·5 E.		......	......	......		......	......	......		Kellett.
At sea	52 26	161 48	1850·0	6 18 E.	......	6·3 E.		......	......	......		......	......	......		Kellett.
At sea	52 36	161 55	1850·0	6 35 E.	......	6·6 E.		......	......	......		......	......	......		Kellett.
At sea	54 36	163 29	1849·5	6 44 E.	......	6·7 E.		......	......	......		......	......	......		Kellett.
At sea	53 36	165 34	1850·0	7 15 E.	......	7·3 E.		......	......	......		......	......	......		Kellett.
At sea	51 39	165 51	1845·5	......	......	......		63 34	......	63·6		......	......	......		Moore.
At sea	50 24	166 20	1854·5	......	......	......		62 45	......	62·8		......	......	......		Collinson.
At sea	53 57	166 32	1850·0	7 47 E.	......	7·8 E.		......	......	......		......	......	......		Kellett.

ZONE III.—Lat. 50° to 55° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.	Inclination. Observed.	Inclination. Cor. to Epoch 1842·5.	Inclination. Corrected.	Force in British units. Observed.	Force in British units. Cor. to Epoch 1842·5.	Force in British units. Corrected.	Observers.
	° ′	° ′		° ′	° ′	°	° ′	′	°				
At sea	50 50	166 37	1850·5	5 54 E.	......	5·9 E.	......	......	......	......	......	......	Collinson.
At sea	51 02	166 52	1854·5	......	......	......	64 22	......	64·4	......	......	......	Collinson.
At sea	52 05	167 12	1851·5	6 05 E.	......	6·1 E.	......	......	......	......	......	......	Collinson.
At sea	51 25	167 48	1845·5	......	......	......	63 11	......	63·2	......	......	......	Moore.
At sea	53 46	168 20	1845·5	......	......	......	65 26	......	65·4	......	......	......	Moore.
At sea	54 16	168 36	1850·0	9 30 E.	......	9·5 E.	......	......	......	......	......	......	Kellett.
At sea	51 54	168 38	1854·5	8 36 E.	......	8·6 E.	......	......	......	......	......	......	Collinson.
At sea	53 35	169 45	1850·5	10 20 E.	......	10·3 E.	......	......	......	......	......	......	Collinson.
At sea	52 45	170 03	1854·5	9 25 E.	......	9·4 E.	......	......	......	......	......	......	Collinson.
At sea	53 38	170 18	1850·5	......	......	......	65 20	......	65·3	......	......	......	Collinson.
At sea	53 39	171 52	1854·5	......	......	......	64 50	......	64·8	......	......	......	Collinson.
At sea	54 35	173 29	1854·5	......	......	......	66 31	......	66·5	......	......	......	Collinson.
Amchitcha	51 27	178 20	1830·0	14 05 E.	......	14·1 E.	......	......	......	......	......	......	Etoline.
At sea	51 03	185 00	1849·5	18 18 E.	......	18·3 E.	......	......	......	......	......	......	Crane.
At sea	51 03	185 00	1849·5	17 35 E.	......	17·6 E.	......	......	......	......	......	......	Kellett.
Atcha	52 17	185 48	1830·0	16 21 E.	......	16·4 E.	......	......	......	......	......	......	Etoline.
At sea	53 31	186 13	1849·5	19 08 E.	......	19·1 E.	......	......	......	......	......	......	Crane.
At sea	53 31	186 13	1849·5	18 09 E.	......	18·2 E.	......	......	......	......	......	......	Kellett.
At sea	52 53	187 36	1849·5	19 52 E.	......	19·9 E.	......	......	......	......	......	......	Crane.
At sea	52 53	187 36	1849·5	18 53 E.	......	18·9 E.	......	......	......	......	......	......	Kellett.
At sea	50 29	189 46	1849·5	20 35 E.	......	20·6 E.	......	......	......	......	......	......	Crane.
At sea	50 29	189 46	1849·5	19 14 E.	......	19·2 E.	......	......	......	......	......	......	Kellett.
Unalashka	53 54	193 30	1829·0	19 54 E.	......	19·9 E.	68 26	......	68·4	12·47	......	12·47	Lütke.
Croyalgu Island	54 17	195 13	1826·5	20 50 E.	......	20·8 E.	......	......	......	......	......	......	Beechey.
At sea	51 54	198 37	1827·0	20 27 E.	......	20·5 E.	......	......	......	......	......	......	Lütke.
At sea	54 08	198 43	1850·5	20 20 E.	......	20·3 E.	70 55	......	70·9	......	......	......	Collinson.
At sea	50 21	199 04	1830·5	21 05 E.	......	21·1 E.	......	......	......	......	......	......	Erman.
At sea	50 28	200 38	1830·5	24 29 E.	......	24·5 E.	......	......	......	......	......	......	Erman.
At sea	51 53	202 22	1850·5	......	......	......	69 45	......	69·8	......	......	......	Collinson.
At sea	50 59	203 12	1830·5	25 37 E.	......	25·6 E.	......	......	......	......	......	......	Erman.
At sea	51 03	203 24	1830·5	......	......	......	67 17	......	67·3	11·81	......	11·81	Erman.
At sea	51 46	207 24	1830·5	24 05 E.	......	24·1 E.	......	......	......	......	......	......	Erman.
At sea	53 00	210 04	1830·5	25 33 E.	......	25·6 E.	......	......	......	......	......	......	Erman.
At sea	53 35	213 25	1830·5	......	......	......	71 06	......	71·1	12·34	......	12·34	Erman.
At sea	53 36	216 22	1850·5	24 46 E.	......	24·8 E.	......	......	......	......	......	......	Collinson.
At sea	51 55	216 27	1827·0	24 30 E.	......	24·5 E.	......	......	......	......	......	......	Lütke.
At sea	54 27	221 01	1830·5	......	......	......	73 36	......	73·6	12·79	......	12·79	Erman.
Anchor Cove	53 12	227 46	1866·5	24 59 E.	......	25·0 E.	......	......	......	......	......	......	Pender.
Fort Simpson	54 34	229 35	1862·5	......	......	......	74 53	......	74·9	......	......	......	Richards.
Alpha Bay	53 52	229 42	1866·5	26 34 E.	......	26·6 E.	......	......	......	......	......	......	Pender.
Carter Bay	52 50	231 35	1866·5	25 59 E.	......	26·0 E.	......	......	......	......	......	......	Pender.
Kynumft Harbour	52 12	231 48	1866·5	26 10 E.	......	26·2 E.	......	......	......	......	......	......	Pender.
Safety Cove	51 32	232 03	1864·5	23 38 E.	......	23·6 E.	......	......	......	......	......	......	Pender.
Treadmill Harbour	51 06	232 26	1864·5	24 08 E.	......	24·1 E.	......	......	......	......	......	......	Pender.
Beaver Harbour	50 43	232 35	1860·5	......	......	...... } 24·5 E.	72 37	......	72·6	......	......	......	Richards.
			1861·5	24 [illegible] E.	......	24·7 E.	......	......	......	......	......	......	Pender.
			1865·5	24 24 E.	......	24·4 E.	......	......	......	......	......	......	Pender.
			1863·5	24 30 E.	......	24·5 E.	......	......	......	......	......	......	Pender.
Tracey Harbour	50 51	233 07	1863·5	26 40 E.	......	26·7 E.	......	......	......	......	......	......	Pender.
N. Bentinck Arm	52 23	233 12	1864·5	24 46 E.	......	24·8 E.	......	......	......	......	......	......	Pender.
Port Neville	50 31	233 56	1860·5	......	......	......	72 19	......	72·3	......	......	......	Richards.
Squirrel Cove	50 08	235 03	1864·5	23 56 E.	......	23·9 E.	......	......	......	......	......	......	Pender.
Frazer Lake	54 03	235 20	1833·5	......	......	......	75 48	......	75·8	12·97	......	12·97	Douglas.
Stuart's Lake	54 27	235 40	1833·5	......	......	......	76 09	......	76·2	13·05	......	13·05	Douglas.
Fort Alexandria	52 33	237 31	1833·5	......	......	......	74 50	......	74·8	12·82	......	12·82	Douglas.
Thompson's River	50 41	239 49	1833·5	......	......	......	73 43	......	73·7	12·72	......	12·72	Douglas.
Fort Assiniboine	54 20	245 32	1844·5	24 39 E.	......	24·7 E.	78 15	......	78·3	......	......	......	Lefroy.
Pembina River	54 08	246 06	1844·5	22 23 E.	......	22·4 E.	77 55	......	77·9	......	......	......	Lefroy.
Fort Edmonton	53 31	247 08	1844·5	24 16 E.	......	24·3 E.	77 54	......	77·9	13·86	......	13·86	Lefroy.
Saskatchewan River	54 05	248 16	1844·5	24 26 E.	......	24·4 E.	78 05	......	78·1	13·71	......	13·71	Lefroy.
Saskatchewan River	53 50	249 30	1844·5	24 27 E.	......	24·5 E.	78 34	......	78·6	13·84	......	13·84	Lefroy.
Fort Pitt	53 34	250 41	1844·5	23 09 E.	......	23·2 E.	78 41	......	78·7	14·15	......	14·15	Lefroy.
Saskatchewan River	53 07	251 30	1844·5	......	......	......	78 28	......	78·5	14·24	......	14·24	Lefroy.

ZONE III.—Lat. 50° to 55° N. (continued).

[illegible]	[illegible]	[illegible]	[illegible]	Declination. [illegible]	[illegible]	[illegible]	[illegible]	Inclination. [illegible]	[illegible]	[illegible]	[illegible]	Force in British units. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]										[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]										[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]
Carlton House	52 51	253 47	1820·5	20 45 E.	1 50 E.	22 8 E.	22·7 E.	......	......	......	78·5	......	......	......	13·74	Franklin.
			1844·5	22 55 E.	0 10 W.	22·7 E.		78 31	......	78·5		13·74	......	13·74		Lefroy.
Saskatchewan River ...	53 16	255 12	1844·5	24 45 E.	0 10 W.	24·6 E.		79 11	......	79·2		13·94	......	13·94		Lefroy.
Carp Portage	54 47	257 21	1843·5	24 17 E.	0 05 W.	24·2 E.		80 40	......	80·7		......	......	......		Lefroy.
Cumberland House ...	53 57	257 41	1825·5	19 14 E.	?	?	19·5 E.	......	......	......	80 4	......	......	......	14·12	Franklin.
			1843·5	19 36 E.	0 05 W.	19·5 E.		80 25	......	80·4		14·12	......	14·12		Lefroy.
Beaver Lake	54 32	257 50	1843·5	22 00 E.		22·0 E.		80 34	......	80·6		14·14	......	14·14		Lefroy.
Fort Pelly	51 45	257 55	1837·5	17 00 E.	0 25 E.	17·4 E.		......	......	......		......	......	......		Simpson.
[illegible] Pass	53 48	258 34	1844·0	20 17 E.	......	20·3 E.		80 24	......	80·4		14 32	......	14·32		Lefroy.
[illegible] Island...	53 19	259 20	1844·0	18 06 E.	......	18·1 E.		80 00	......	80 0		13·82	......	13·82		Lefroy.
Cedar Lake	53 12	259 30	1843·5	......	......	......		80 07	......	80·1		14·16	......	14·16		Lefroy.
Cross Lake	53 10	260 28	1843·5	18 03 E.	......	18·1 E.		80 28	......	80·5		14·20	......	14·20		Lefroy.
Grand Rapid	53 08	260 32	1844·0	......	......	......		80 27	......	80·5		14·15	......	14·15		Lefroy.
Lake Winnipeg.........	53 31	260 48	1843·5	......	......	......		80 17	......	80·3		14·09	......	14·09		Lefroy.
Lake Winnipeg.........	53 34	260 56	1843·5	17 00 E.	......	17·0 E.		......	......	......		......	......	......		Lefroy.
Norway House	53 59	261 53	1844·5	15 13 E.	......	15·2 E.		81 10	......	81·2		14·18	......	14·18		Lefroy.
Old N[illegible]	[illegible]	[illegible] 59	1843·5	......	......	......		80 45	......	80·8		14·18	......	14·18		Lefroy.
Lake W[illegible]	[illegible]	[illegible] 47	1843·5	......	......	......		80 05	.... .	80·1		14·12	......	14·12		Lefroy.
Hairy Lake	54 21	262 49	1843·5	18 44 E.	......	18·7 E.		81 21	......	81·4		14·07	......	14·07		Lefroy.
Lake Winnipeg.........	52 22	262 51	1844·5	......	......	......		80 24	......	80·4		14·30	......	14·30		Lefroy.
Lake Winnipeg.........	52 15	262 53	1843·5	15 37 E.	......	15·6 E.		......	......	......		......	......	......		Lefroy.
Lake Winnipeg.........	51 45	263 07	1843·5	15 57 E.	......	15·9 E.		79 28	......	79·5		14·42	......	14·42		Lefroy.
Lake Winnipeg.........	51 04	263 15	1843·5	14 14 E.	......	14·2 E.		79 12	......	79·2		14·10	......	14·10		Lefroy.
Mouth of Red River...	50 19	263 17	1843·5	......	......	......		78 33	......	78·6		14·11	......	14·11		Lefroy.
Lake Winnipeg.........	51 36	263 18	1844·0	15 42 E.	......	15·7 E.		79 06	......	79·1		14·40	......	14·40		Lefroy.
Lake Winnipeg.........	50 27	263 22	1843·5	15 30 E.	0 04 E.	15·6 E.		79 05	......	79·1		14·13	......	14·13		Lefroy.
Lake Winnipeg.........	50 28	263 25	1857·5	14 25 E.	1 00 E.	15·4 E.		......	......	......		......	......	......		Palliser.
Whitefall Portage......	54 24	263 34	1843·5	17 32 E.	0 04 E.	17·6 E.		......	......	.. ..		14·15	......	14·15		Lefroy.
Fort Alexander	50 37	263 39	1834·0	......	......	......	14·4 E.	78 54	......	78·9	78·9	......	......	......	14·06	Back.
			1844·0	14 14 E.	0 08 E.	14·4 E.		78 57	......	78·9		14·46	......	14·06		Lefroy.
Lake Winnipeg.........	51 04	263 39	1844 0	......	......	......		79 32	......	79·5		14·52	......	14·52		Lefroy.
Pinaway Portage	50 12	263 57	1843·5	12 48 E.	0 05 E.	12·9 E.		......	......	......		......	......	......		Lefroy.
Windy Lake	54 37	263 58	1843·5	......	......	......		81 57	......	82·0		14·15	......	14·15		Lefroy.
Holy Lake...............	54 51	264 14	1843·5	14 53 E.	0 05 E.	15·0 E.		......	......	......		......	......	......		Lefroy.
Slave Portage	50 11	264 23	1843·5	......	......	......		78 57	......	79·0		14·13	......	14·13		Lefroy.
Oxford House	54 56	264 30	1843·5	......	......	......		82 39	......	82·7		14·21	......	14·21		Lefroy.
Knee Lake...............	54 51	264 49	1843·5	14 24 E.	0 05 E.	14·5 E.		......	......	......		......	......	......		Lefroy.
Winnipeg River	50 10	264 51	1844·0	11 55 E.	0 07 E.	12·0 E.		......	......	......		14·21	......	14·21		Lefroy.
At sea......................	54 43	278 28	1846·5	13 30 W.	......	13·5 W.		83 47	......	83·8		13·84	......	13·84		Moore.
At sea......................	53 57	278 30	1846·5	......	......	......		83 02	......	83·0		13·79	......	13·79		Moore.
At sea......................	53 42	278 51	1846·5	12 48 W.	......	12·8 W.		......	......	......		13·89	......	13·89		Moore.
At sea......................	53 24	278 54	1846·5	......	......	......		82 20	......	82·3		......	......	......		Moore.
Moose Factory	51 15	279 04	1846·5	12 40 W.	0 20 E.	12·3 W.		81 30	......	81·5		14·12	......	14·12		Moore.
At sea......................	53 10	279 12	1846·5	12 30 W.	......	12·5 W		......	......	......		......	......	......		Moore.
On shore	51 18	279 16	1846·5	10 55 W.	0 20 E.	10·6 W.		81 02	......	81·0		14·07	......	14·07		Moore.
At sea......................	51 32	279 26	1846·5	10 41 W.	......	10·7 W.		80 59	......	81·0		......	......	......		Moore.
At sea......................	51 17	279 34	1846·5	12 40 W.	......	12·7 W.		......	......	......		......	......	......		Moore.
At sea......................	52 20	279 43	1846·5	......	......	......		81 49	......	81·8		......	......	......		Moore.
Bay of Seven Islands...	50 13	293 35	1831·5	23 34 W.	0 55 W.	24·5 W.		......	......	......		......	......	......		Bayfield.
Moisier River	50 11	293 55	1831·5	24 08 W.	0 55 W.	25·1 W.		......	......	......		......	......	......		Bayfield.
At sea......................	50 04	295 41	1842·5	24 24 W.	......	24·4 W.		79 46	......	79·8		......	......	......		Lefroy.
Mingan Harbour	50 17	295 58	1831·5	25 30 W.	0 55 W.	26·4 W.		......	......	......		......	......	......		Bayfield.
At sea......................	50 02	296 34	1842·5	28 36 W.	......	28·6 W.		79 42	......	79·7		......	......	......		Lefroy.
Betchewa Harbour ...	50 14	296 49	1832·5	27 31 W.	0 50 W.	28·4 W.		......	......	......		......	......	......		Bayfield.
Nabosippe River	50 14	297 48	1832·5	28 08 W.	0 50 W.	29·0 W.		......	......	......		......	......	......		Bayfield.
Kegashka Bay	50 11	298 44	1832·5	28 47 W.	0 50 W.	29·6 W.		......	......	......		......	......	......		Bayfield.
Head of Hamilton Inl.	53 32	299 51	1860·5	39 03 W.	1 30 E.	37·6 W.		79 56	......	79·9		......	......	......		M'Clintock.
Cape Whittle...........	50 11	299 52	1832·5	29 22 W.	0 50 W.	30·2 W.		......	......	......		......	......	......		Bayfield.
Little Meccatina	50 33	300 43	1833·5	29 33 W.	0 45 W.	30·3 W.		......	......	......		......	......	......		Bayfield.
Great Meccatina	50 44	300 59	1833·5	30 00 W.	0 45 W.	30·8 W.		......	......	......		......	......	......		Bayfield.

ZONE III.—Lat. 50° to 55° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Ob-served.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.	Inclination. Ob-served.	Inclination. Cor. to Epoch 1842·5.	Inclination. Corrected.	Force in British units. Ob-served.	Force in British units. Cor. to Epoch 1842·5.	Force in British units. Corrected.	Observers.
	° ′	° ′		° ′	° ′	°	° ′		°				
Rigoulotte	54 11	301 35	1860·5	41 09 w.	1 30 E.	39·7 w.	80 05	......	80·1	......	......	......	M'Clintock.
Mistanoque Harbour	51 16	301 47	1834·5	31 15 w.	0 40 w.	31·9 w.	......	......	......	......	......	......	Bayfield.
[illegible]	51 22	302 06	1860·5	40 39 w.	1 30 E.	39·2 w.	......	......	......	......	......	......	M'Clintock.
Belles Amours Harb.	51 27	302 33	1834·5	32 00 w.	0 40 w.	32·7 w.	......	......	......	......	......	......	Bayfield.
Bradore Harbour	51 28	302 45	1834·5	32 30 w.	0 40 w.	33·2 w.	......	......	......	......	......	......	Bayfield.
Forteaw Bay	51 28	303 03	1833·5	32 26 w	0 45 w.	33·2 w.	......	......	......	......	......	......	Bayfield.
Green Island	51 24	303 26	1833·5	33 30 w.	0 45 w.	34·3 w.	......	......	......	......	......	......	Bayfield.
Red Bay	51 44	303 34	1835·5	34 30 w.	0 35 w.	35·1 w.	......	......	......	......	......	......	Bayfield.
Chateau Bay	52 00	304 09	1835·5	35 30 w.	0 35 w.	36·1 w.	......	......	......	......	......	......	Bayfield.
Cape St. Lewis	52 21	304 21	1835·5	37 30 w.	0 35 w.	38·1 w.	......	......	......	......	......	......	Bayfield.
At sea	54 00	316 24	1846·5	44 00 w.	......	44·0 w.	......	......	......	......	......	......	Moore.
At sea	52 28	321 12	1846·5	......	......	......	76 18	......	76·3	......	......	......	Moore.
At sea	52 17	321 45	1846·5	39 18 w.	......	39·3 w.	......	......	......	......	......	......	Moore.
At sea	51 47	325 00	1846·5	37 40 w.	......	37·7 w.	75 11	......	75·2	......	......	......	Moore.
At sea	51 33	325 46	1846·5	37 29 w.	......	37·5 w.	74 42	......	74·7	......	......	......	Moore.
At sea	51 10	327 09	1846·5	37 43 w.	......	37·7 w.	......	......	......	......	......	......	Moore.
At sea	50 14	330 46	1846·5	35 55 w.	......	35·9 w.	73 41	......	73·7	......	......	......	Moore.
At sea	53 39	347 28	1853·5	31 26 w.	......	31·4 w.	......	......	......	......	......	......	Staunton.
At sea	50 10	357 10	1846·5	......	......	......	68 34	......	68·6	10·01	......	10·01	Moore.
At sea	50 17	357 26	1840·5	......	......	......	68 48	......	68·8	10·29	......	10·29	Ross.
At sea	50 40	358 25	1830·5	26 15 w.	......	26·3 w.	......	......	......	......	......	......	Erman.
Portsmouth	50 44	358 52	1830·5	......	......	......	68 33	......	68·6	10·23	......	10·23	Erman.

ZONE IV.—LATITUDE 55° TO 60° N.

To this Zone belong the Stations (89 in number) comprised between the latitudes of 55° and 60°, forming part of the Magnetic Survey of the British Islands, Phil. Trans. 1870, Art. XIV. It has not been deemed necessary to reprint those Stations in this communication as they may be so easily referred to.

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ZONE IV.—Lat. 55° to 60° N.

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.		Inclination. Observed.	Inclination. Cor. to Epoch 1842·5.	Inclination. Corrected.		Force in British units. Observed.	Force. Cor. to Epoch 1842·5.	Force. Corrected.		Observers.
	° ′	° ′		° ′	° ′	°		° ′	° ′	°						
Flokkeröe	58 05	8 01	1844·5	......	......	......		71 39	+0 03	71·7		10·50	......	10·50		Danish Officers.
Kolding	55 27	9 24	1824·5	......	......	......		70 50	−0 27	70·4		10·56	−0·03	10·53		Hansteen.
Heggen	59 54	9 52	1825·5	......	......	......		73 47	−0 25	73·4		10·98	−0·03	10·95		Hansteen.
Aalberg	57 03	9 56	1824·5	......	......	......		71 27	−0 27	71·0		10·22	−0·03	10·19		Hansteen.
Johnsrud	59 58	10 23	1825·5	......	......	......		73 23	−0 25	73·0		11·05	−0·03	11·02		Hansteen.
Christiania	59 55	10 43	1842·5	18 36 w.	0 00	18·6 w.		71 45	0 00	71·8		10·75	0·00	10·75		Hansteen.
Corsoer	55 20	11 07	1858·0	16 25 w.	1 17 w.	17·7 w.		69 36	+0 23	70·0		10·38	+0·03	10·41		Lamont.
[illegible]	59 10	11 23	1828·5	19 46 w.	1 10 E.	18·6 w.		72 29	−0 21	72·1		10·57	−0·03	10·54		Hansteen.
[illegible]	[illegible] 42	11 51	1842·5	......	......	......		71 05	0 00	71·1		10·52	0·00	10·52		Hansteen.
Tangelanda	58 35	12 08	1828·5	18 42 w.	1 10 E.	17·5 w.		71 46	−0 21	71·4		10·57	−0·03	10·54		Hansteen.
Wenersborg	58 22	12 22	1828·5	......	......	......		71 44	−0 21	71·4		10·53	−0·03	10·50		Hansteen.
Copenhagen	55 41	12 35	1842·5	......	......	......		69 50	0 00	69·8	69·8	10·41	0·00	10·40		Hansteen.
			1858·0	15 12 w.	1 17 w.	16·5 w.		69 28	+0 23	69·8		10·37	+0·03			Lamont.
Carlstad	59 23	13 30	1825·5	......	......	......		72 33	−0 25	72·1		10·69	−0·03	10·66		Hansteen.
Mariestad	58 42	13 53	1828·5	......	......	......		71 42	−0 21	71·4		10·51	−0·03	10·48		Hansteen.
Ystad	55 26	13 56	1824·5	......	......	......		70 13	−0 27	69·8		......	......	......		Erichsen.
[illegible]	[illegible] 38	14 08	1828·5	......	......	......		71 43	−0 21	71·4		10·51	−0·03	10·48		Hansteen.
[illegible]	[illegible] 35	14 23	1828·5	17 41 w.	1 10 E.	16·5 w.		71 34	−0 21	71·2		10·41	−0·03	10·38		Hansteen.
[illegible]	[illegible] 33	14 30	1828·5	17 26 w.	1 10 E.	16·3 w.		......	......	......		......	......	......		Hansteen.
Motala	58 36	14 57	1828·5	16 38 w.	1 10 E.	15·5 w.		......	......	......		......	......	......		Hansteen.
Orebro	59 17	15 13	1830·5	......	......	......		71 56	−0 18	71·6		10·63	−0·03	10·60		Hansteen.
Linköping	58 24	15 41	1828·5	......	......	......		71 22	−0 21	71·0		10·35	−0·03	10·32		Hansteen.
Norrköping	58 36	16 11	1828·5	......	......	......		71 27	−0 21	71·1		10·43	−0·03	10·40		Hansteen.
Stockholm	59 20	18 03	1830·5	14 54 w.	1 00 E.	13·9 w.	14·0 w.	71 45	−0 18	71·5	71·4	10·62	−0·03	10·59	10·51	Hansteen.
			1833·0	14 58 w.	0 53 E.	14·1 w.		71 40	−0 14	71·4		10·32	−0·02	10·30		Rudberg.
			1842·5	......	......	......		71 22	0 00	71·4		10·57	0·00	10·57		Hansteen.
			1851·5	......	......	......		71 14	+0 14	71·5		10·56	+0·03	10·59		Hansteen.
Sandkrug	55 42	21 08	1829·5	......	......	......		69 40	−0 20	69·3		......	......	......		Humboldt.
Arensburg	58 15	22 25	1848·5	......	......	......		70 51	+0 09	71·0		10·39	−0·01	10·38		Kämtz, L. S.
Kobbit	58 20	22 40	1848·5	......	......	......		71 09	+0 09	71·3		10·14	−0·01	10·13		Kämtz, L. S.
Werder	58 35	23 40	1848·5	......	......	......		69 32	+0 09	69·7		10·36	−0·01	10·35		Kämtz, L. S.
Pernau	58 22	24 32	1848·5	......	......	......		70 36	+0 09	70·8		10·32	−0·01	10·31		Kämtz, L. S.
Rewal	59 35	24 43	1848·5	......	......	......		70 50	+0 07	71·0		10·35	0·00	10·35		Kämtz, L. S.
Nawast	58 35	25 34	1848·5	......	......	......		70 41	+0 07	70·8		10·29	0·00	10·29		Kämtz, L. S.
Kardis	58 51	26 17	1848·5	......	......	......		70 17	+0 07	70·4		10·39	0·00	10·39		Kämtz, L. S.
Uellenorm	58 19	26 43	1847·5	......	......	......		70 10	+0 06	70·3		10·46	0·00	10·46		Kämtz, L. S.
Dorpat	58 23	26 43	1828·5	9 01 w.	1 24 E.	7·6 w.	7·8 w.	......	......	......	70·8	......	......	......		Kämtz, L. S.
			1832·5	8 56 w.	1 00 E.	7·9 w.		70 45	−0 13	70·5		......	......	......		Fedorow.
			1837·5	8 29 w.	0 30 E.	8·0 w.		......	......	......		......	......	......		Struve.
			1850·5	......	......	......		70 51	+0 10	71·0		10·67	......	10·67		Kämtz, L. S.
Petersburg	59 56	30 19	1828·5	6 48 w.	?	......	6·3 w.	71 06	−0 18	70·8	71·0	10·60	−0·02	10·58	1·61	Erman.
			1828·5	6 41 w.	?	......		71 18	−0 18	71·0		10·66	−0·02	10·64		Hansteen.
			1829·5	......	?	......		71 12	−0 17	70·9		......	......	......		Humboldt.
			1832·5	......	?	......		71 10	−0 13	71·0		......	......	......		Kupffer.
			1842·5	6 18 w.	......	6·3 w.		71 00	0 00	71·0		......	......	......		Observatory.
			1867·5	......	?	......		70 46	+0 31	71·3		......	......	......		Fritsche.
			1869·5	2 26 w.	?	......		70 45	+0 33	71·3		10·70	?	?		Wild.
			1870·5	2 05 w.	?	......		70 45	−0 34	71·3		......	......	......		Rikatscheff.
Schlisselburg	59 57	31 02	1870·5	......	......	......		70 39	−0 35	71·2		9·97	.....	9·97		Belavenetz.
Pomerania	59 20	31 16	1828·5	......	......	......		71 01	−0 17	70·7		10·67	0·02	10·65		Erman.
Novgorod	58 31	31 19	1828·5	6 21 w.	1 27 E.	4·9 w.	5·0 w.	70 25	−0 16	70·2	70·25	10·77	−0·02	10·75	10·75	Erman.
			1828·5	6 26 w.	1 27 E.	5·0 w.		70 35	−0 13	70·3		......	......	......		Hansteen.
Rachino	58 07	32 43	1830·5	......	......	......		70 39	−0 13	70·4		10·65	−0·02	10·63		Hansteen.
Waldai	57 56	33 15	1828·5	......	......	......		69 58	−0 16	69·7	69·8	10·82	−0·02	10·80	10·70	Erman.
			1830·0	5 50 w.	1 25 E.	4·4 w.		70 12	−0 16	69·9		10·63	−0·02	10·61		Hansteen.
Wolotschok	57 37	34 40	1828·5	......	......	......		69 52	−0 15	69·6	69·7	10·66	−0·02	10·64	10·64	Erman.
			1830·5	4 20 w.	1 25 E.	2·9 w.		70 01	−0 13	69·8		......	......	......		Hansteen.
Torschok	57 02	35 03	1830·5	......	......	......		69 25	−0 13	69·2		10·77	−0·02	10·75		Hansteen.
Twer	56 52	35 57	1828·5	......	......	......		68 32	−0 14	68·3	68·6	10·49	−0·02	10·47	10·47	Erman.
			1867·5	......	......	......		68 28	+0 25	68·9		......	......	......		Fritsche.

ZONE IV.—Lat. 55° to 60° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.		Inclination. Observed.	Inclination. Cor. to Epoch 1842·5.	Inclination. Corrected.		Force in British units. Observed.	Force in British units. Cor. to Epoch 1842·5.	Force in British units. Corrected.		Observers.
Moscow	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Bogorodsk	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]									[illegible]
Platowa	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Vologda	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]
Dmitrewsk	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Wladimir	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]
10 Versts from Sudogd	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]										
Murom	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]
Osablikowo	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
			[illegible]	......	......	......		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		Hansteen.
Teplaia	55 27	42 49	1830·5	......	......	......		67 59	−0 10	67·8		10·73	−0·01	10·72		Hansteen.
[illegible]	56 09	43 34	1828·5	0 23 E.	1 26 E.	1·8 E.	1·8 E.	68 59	−0 11	68·8	68·6	10·94	−0·01	10·93	10·81	Erman.
			1828·5	......	......	......		68 35	−0 11	68·4		10·71	−0·01	10·70		Hansteen.
Nishnei Novgorod	56 19	43 57	1828·5	0 53 E.	1 29 E.	2·4 E.	2·2 E.	68 41	−0 11	68·5	68·5	10·92	−0·01	10·91	10·83	Erman.
			1828·5	......	......	......		68 33	−0 11	68·4		10·77	−0·01	10·76		Hansteen.
			1867·5	4 39 E.	2 36 W.	2·0 E.		68 45	?	?		......	......	......		Fritsche.
Tschugumi	56 06	45 40	1828·5	1 27 E.	1 30 E.	3·0 E.	3·0 E.	68 39	−0 10	68·5	68·5	11·02	−0·01	11·01	10·97	Erman.
			1828·5	......	......	......		68 39	−0 10	68·5		10·94	−0·01	10·93		Hansteen.
Angikowa	55 44	48 09	1828·5	1 37 E.	1 29 E.	3·1 E.	3·1 E.	68 35	−0 10	68·4	68·4	11·03	−0·01	11·10	10·96	Erman.
			1828·5	......	......	......		68 35	−0 10	68·4		10·94	−0·01	10·93		Hansteen.
Kasan	55 48	49 07	1828·5	2 22 E.	1 32 E.	3·9 E.	3·7 E.	68 21	−0 08	68·2	68·4	10·92	−0·01	10·91	10·92	Erman.
			1828·5	......	......	......		68 27	−0 08	68·3		10·90	−0·01	10·89		Hansteen.
			1829·5	......	......	......		68 27	−0 07	68·3		10·92	−0·01	10·91		Humboldt.
			1830·5	......	......	......		68 26	−0 06	68·3		......	......	......		Fuss.
			1832·5	2 34 E.	0 59 E.	3·6 E.		68 24	−0 05	68·3		......	......	......		Simonoff.
			1841·5	3 24 E.	0 06 E.	3·5 E.		68 22	0 00	68·3		......	......	......		Simonoff.
			1842·5	......	......	......		68 26	0 00	68·4		......	......	......		Observatory.
			1850·5	......	......	......		68 31	−0 01	68·5		10·85	0·00	10·85		Sawalief.
			1867·5	6 05 E.	2 31 W.	3·5 E.		68 27	−0 02	68·4		......	......	......		Fritsche.
			1869·5	6 12 E.	2 43 W.	3·5 E.		68 40	−0 02	68·6		11·02	0·00	11·02		Wild.
Mitioschka	56 13	49 55	1828·5	2 43 E.	1 35 E.	4·3 E.	4·3 E.	68 46	−0 08	68·6	68·7	11·08	−0·01	11·07	11·06	Erman.
			1828·5	......	......	......		68 55	[illegible]	[illegible]		11·06	−0·01	11·05		Hansteen.
Milet	56 40	50 38	1828·5	......	......	......	6·7 E.	[illegible]	[illegible]	[illegible]	68·7	11·14	−0·01	11·13	11·1[illegible]	Erman.
			1828·5	5 09 E.	1 35 E.	6·7 E.		68 50	−0 08	68·7		11·17	−0·01	11·16		Hansteen.
Kojil	57 12	51 25	1828·5	......	......	......		69 22	−0 07	69·2		11·30	0·00	11·30		Hansteen.
Suri	57 33	53 04	1828·5	......	......	......		70 20	−0 07	70·2	70·3	11·19	0·00	11·19	11·24	Erman.
			1828·5	......	......	......		70 36	−0 07	70·5		11·29	0·00	11·29		Hansteen.
Dubrowa	57 42	54 30	1828·5	6 00 E.	1 41 E.	7·7 E.	7·7 E.	69 52	−0 06	69·8	69·8	11·27	0·00	11·27	11·32	Erman.
			1828·5	......	......	......		69 56	−0 06	69·8		11·37	0·00	11·37		Hansteen.
Ochansk	57 47	55 09	1828·5	......	......	......		70 13	−0 06	70·1		11·44	0·00	11·44		Hansteen.
Asamatowa	55 36	56 06	1830·0	......	......	......		68 16	−0 05	68·2		11·20	0·00	11·20		Hansteen.
Kultavka	57 57	56 08	1828·5	5 54 E.	1 44 E.	7·6 E.		......	......	......		......	......	......		Hansteen.
Perm	58 00	56 14	1828·5	6 21 E.	1 44 E.	8·1 E.	7·7 E.	70 02	−0 06	69·9	70·0	11·29	0·00	11·29	11·36	Erman.
			1828·5	6 04 E.	1 44 E.	7·8 E.		70 09	−0 06	70·1		11·42	0·00	11·42		Hansteen.
			1830·5	......	......	......		69 54	−0 05	69·8		......	......	......		Fuss.
			1867·5	9 35 E.	2 24 W.	7·2 E.		70 24	−0 17	70·1		......	......	......		Fritsche.
Jänygi	57 42	56 36	1828·5	6 23 E.	1 43 E.	8·1 E.		......	......	......		......	......	......		Hansteen.
Krylasowo	57 34	56 37	1828·5	6 10 E.	1 43 E.	7·9 E.	7·8 E.	70 01	−0 05	69·9	70·0	11·57	0·00	11·57	11·52	Erman.
			1828·5	6 07 E.	1 43 E.	7·8 E.		70 03	−0 05	70·0		11·48	0·00	11·48		Hansteen.
Aprelowa	55 44	57 00	1830·0	......	......	......		68 31	−0 05	68·4		11·32	0·00	11·32		Hansteen.
Buikowa	56 53	57 26	1828·5	7 11 E.	1 42 E.	8·9 E.	8·8 E.	69 50	−0 05	69·8	69·8	11·49	0·00	11·49	11·49	Erman.
			1828·5	7 03 E.	1 42 E.	8·8 E.		69 51	−0 05	69·8		11·50	0·00	11·50		Hansteen.
Masigutowa	55 33	58 05	1830·0	......	......	......		68 18	−0 04	68·2		11·31	0·00	11·31		Hansteen.
Klenowskaia	56 50	58 44	1828·5	6 50 E.	1 43 E.	8·6 E.		......	......	......		......	......	......		Hansteen.
Satkinskoi	55 08	58 58	1829·5	......	......	......		67 43	−0 04	67·7		11·39	0·00	11·39		Hansteen.

ZONE IV.—Lat. 55° to 60° N. (continued).

Kuschwa	58 18	59 42	1828·5	7 57 E.	1 48 E.	9·7 E.		......	......	......	70·8	......	......	......	11·45	Hansteen.
			1828·5	7 46 E.	1 48 E.			70 51	−0 04	70·8		11·45	0·00	11·45		Erman.
Zlatoust	55 08	59 50	1829·5	5 25 E.	1 41 E.	7·1 E.	7·1 E.	67 44	−0 03	67·7	67·7	11·41	0·00	11·41	[illegible]	[illegible]
			1829·5	......	......	......		67 43	−0 03	67·7		......	......	......		[illegible]
N. Tagilsk	57 55	59 59	1828·5	5 53 E.	1 47 E.	7·7 E.	7·7 E.	69 47	−0 04	69·7	69·6	11·50	0·00	11·50	11·50	Hansteen.
			1829·5	......	......	......		69 30	−0 04	69·4		......	......	......		Humboldt.
N. Turinsk	58 41	60 00	1828·5	......	......	......		71 02	−0 04	71·0	71·0	11·73	0·00	11·73	11·73	Hansteen.
			1829·5	......	......	......		70 59	−0 04	71·0		......	......	......		Humboldt.
Bogoslowsk	59 45	60 00	1828·5	9 09 E.	1 49 E.	11·0 E.	11·0 E.	71 36	−0 04	71·5	71·4	11·61	0·00	11·61	11·59	Hansteen.
			1828·5	......	......	......		71 25	−0 04	71·4		11·57	0·00	11·57		Erman.
Newiansk	57 24	60 05	1828·5	......	......	......		69 36	−0 03	69·6		11·59	0·00	11·59		Hansteen.
[illegible]	5[illegible] 54	60 23	1828·5	5 25 E.	1 45 E.	7·2 E.		......	......	......		......	......	......		Hansteen.
Catherinburg	56 50	60 34	1828·5	7 23 E.	1 45 E.	9·1 E.	6·7 E.	69 24	−0 03	69·4	69·5	11·54	0·00	11·54	11·60	Erman.
			1828·5	6 27 E.	1 45 E.	8·2 E.		69 42	−0 03	69·7		11·65	0·00	11·65		Hansteen.
			1829·5	......	......	......		69 10	−0 03	69·1		......	......	......		Humboldt.
			1830·5	......	......	......		69 19	−0 02	69·3		......	......	......		Fuss.
			1832·5	......	......	......		69 15	−0 02	69·2		......	......	......		Fedorow.
			1842·5	6 39 E.	0 00	6·7 E.		69 51	−0 00	69·9		......	......	......		Observatory.
			1867·5	8 33 E.	1 52 W.	6·7 E.		70 07	−0 13	69·9		......	......	......		Fritsche.
Pitalowskoi	59 17	60 36	1828·5	8 38 E.	1 52 E.	10·5 E.		......	......	......		......	......	......		Hansteen.
Nicharoschowa	58 49	60 40	1828·5	6 17 E.	1 50 E.	8·1 E.		......	......	......		......	......	......		Hansteen.
Kyschtim	55 42	60 44	1829·5	......	......	......		68 46	−0 03	68·7		......	......	......		Humboldt.
Beresowsk	56 55	60 45	1829·5	......	......	......		69 13	−0 03	69·2		......	......	......		Humboldt.
Werchoturie	58 52	60 46	1828·5	8 48 E.	1 51 E.	10·39 E.	10·39 E.	70 58	−0 04	70·9	71·0	11·66	0·00	11·66	11·69	Erman.
			1828·5	......	......	......		71 12	−0 04	71·1		11·73	0·00	11·73		Hansteen.
Bjelaika	56 50	61 53	1828·5	......	......	......		69 29	−0 05	69·4	69·4	11·42	0·00	11·42	11·47	Erman.
			1828·5	......	......	......		69 25	−0 05	69·4		11·52	0·00	11·52		Hansteen.
Sugazk	57 00	63 44	1828·5	......	......	......	9·7 E.	69 54	−0 02	69·9	69·7	11·75	+0·01	11·76	11·57	Hansteen.
			1828·5	7 54 E.	1 47 E.	9·7 E.		69 35	−0 02	69·6		11·37	+0·01	11·38		Erman.
Tjumen	57 10	65 27	1828·5	......	......	......	10·5 E.	70 15	−0 02	70·2	70·0	11·85	+0·01	11·86	11·74	Hansteen.
			1828·5	9 09 E.	1 49 E.	10·9 E.		69 45	−0 02	69·7		......	......	......		Erman.
			1830·5	......	......	......		70 02	−0 02	70·0		......	......	......		Fuss.
			1867·5	11 54 E.	1 46 W.	10·1 E.		70 43	−0 32	70·2		11·63	−0·02	11·61		Fritsche.
Jujakowo	57 32	67 06	1828·5	9 17 E.	1 51 E.	11·1 E.	11·1 E.	70 31	−0 01	70·5	70·5	11·90	+0·01	11·91	11·88	Hansteen.
			1828·5	9 14 E.	1 51 E.	11·1 E.		70 29	−0 01	70·5		11·85	+0·01	11·86		Erman.
Chutarbitka	57 58	68 00	1828·5	9 22 E.	1 51 E.	11·2 E.	11·2 E.	70 39	0 00	70·6	[illegible]	[illegible]	[illegible]	[illegible]	11·80	Hansteen.
			1828·5	......	......	......		70 15	0 00	70·3		[illegible]	[illegible]	[illegible]		Erman.
Tobolsk	58 12	68 16	1828·5	9 46 E.	1 54 E.	11·7 E.	11·6 E.	70 58	0 00	71·0	71·0	11·90	+0·01	11·91	11·90	Hansteen.
			1828·5	9 44 E.	1 54 E.	11·6 E.		71 07	0 00	71·1		11·85	+0·01	11·86		Erman.
			1829·5	......	......	......		70 56	0 00	70·9		11·98	+0·01	11·99		Humboldt.
			1830·5	......	......	......		71 02	0 00	71 0		......	......	......		Fuss.
			1833·5	10 20 E.	1 12 E.	11·5 E.		71 02	0 00	71·0		......	......	......		Fedorow.
			1867·5	12 23 E.	?	?		71 29	?	?		11·84	−0·02	11·82		Fritsche.
Uwazk	59 03	68 45	1829·0	......	......	......		71 13	0 00	71·2		12·03	+0·01	12·04		Erman.
Istiätskaia	57 24	68 50	1829·0	......	......	......		70 24	+0 01	70·4		11·84	+0·01	11·85		Hansteen.
Gotopulowa	56 51	69 51	1829·0	......	......	......		70 12	+0 01	70·2		11·99	+0·01	12·00		Hansteen.
Tugalowsk	59 45	69 55	1829·0	......	......	......		72 26	+0 01	72·5		12·01	+0·01	12·02		Erman.
Denjikowo	59 58	69 55	1829·0	10 52 E.	2 02 E.	12·9 E.		......	......	......		......	......	......		Erman.
Balachlaiska	57 42	70 43	1829·0	10 53 E.	1 56 E.	12·8 E.		......	......	......		......	......	......		Hansteen.
Kolotschikowo	56 39	70 45	1829·0	......	......	......		70 21	+0 01	70·4		11·80	+0·01	11·81		Erman.
Orlowa	56 00	70 55	1829·0	......	......	......		69 28	+0 01	69·5		11·59	+0·01	11·60		Hansteen.
Ajewskji Wolok	56 35	71 49	1829·0	9 15 E.	1 49 E.	11·1 E.		......	......	......		......	......	......		Erman.
Tjukalinsk	55 57	72 14	1829·0	9 12 E.	1 49 E.	11·0		69 57	+0 02	70·0	70·0	......	......	......		Erman.
			1867·5	11 23 E.	?	?		70 08	?	?		......	......	......		Fritsche.
Tara	56 54	74 04	1829·0	9 36 E.	1 49 E.	11·4 E.		70 28	+0 03	70·5		12·03	+0·02	12·05		Erman.
Baschenowa	55 40	74 25	1829·0	......	......	......		69 28	+0 03	69·5		12·03	+0·02	12·05		Hansteen.
Mogilnaia	56 01	74 32	1829·0	......	......	......		69 46	+0 03	69·8		12·05	+0·02	12·07		Hansteen.
Muraschewa	55 46	75 35	1829·0	......	......	......		69 41	+0 04	69·8		12·09	+0·02	12·11		Hansteen.
Spaskoie	55 44	76 26	1829·0	......	......	......		69 43	+0 04	69·8		12·11	+0·02	12·13		Hansteen.
Pokrowsk	55 42	77 28	1829·0	......	......	......		69 39	+0 04	69·7		12·28	+0·02	12·30		Erman.
Antoschkino	55 40	77 54	1829·0	......	......	......		69 33	+0 06	69·7		12·09	+0·03	12·12		Hansteen.
Kainsk	55 27	78 18	1829·0	......	......	......		69 36	+0 06	69·7		12·22	+0·03	12·25		Hansteen.

ZONE IV.—Lat. 55° to 60° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.		Inclination. Observed.	Inclination. Cor. to Epoch 1842·5.	Inclination. Corrected.		Force in British units. Observed.	Force. Cor. to Epoch 1842·5.	Force. Corrected.		Observers.
	° ′	° ′		° ′	° ′	°		° ′	° ′	°						
Osinowi Kolki	55 29	78 56	1829·0	......	......	......		69 37	+0 06	69·7		12·24	+0·03	12·27		Hansteen.
Ubinskaia	55 18	79 52	1829·0	......	......	......		69 40	+0 07	69·8		12·24	+0·03	12·27		Hansteen.
Kargask Dubrowa	55 13	80 42	1829·0	......	......	......		69 46	+0 08	69·9		12·18	+0·03	12·21		Hansteen.
Narym	58 54	80 50	1829·0	9 18 E.	2 02 E.	11·3 E.		72 51	+0 08	73·0		12·43	+0·03	12·46		Hansteen.
Tschuluim	55 06	81 14	1829·0	8 59 E.	1 45 E.	10·7 E.		69 33	+0 10	69·7		11·85	+0·03	11·88		Erman.
Owstschinikowa	55 34	82 03	1829·0	9 03 E.	1 47 E.	10·8 E.		69 42	+0 09	69·9		12·25	+0·03	12·28		Hansteen.
Tugursk	58 40	83 00	1829·0	......	......	......		72 24	+0 09	72·6		12·50	+0·03	12·53		Hansteen.
Kolywan	55 20	83 03	1829·0	......	......	......		70 06	+0 09	70·2	70·2	12·38	+0·03	12·41	12·36	Erman.
			1829·0	......	......	......		70 02	+0 09	70·2		12·28	+0·03	12·31		Hansteen.
Taisakowa	58 03	83 30	1829·0	11 40 E.	1 57 E.	13·6 E.		......	......	......		......	......	......		Hansteen.
Anbarsk	57 30	83 33	1829·0	......	......	......		71 53	+0 10	72·1		12·50	+0·03	12·53		Due.
Bolotna	56 00	83 56	1829·0	......	......	......		70 22	+0 10	70·5		12·36	+0·04	12·40		Due.
Ojasch	55 37	84 00	1829·0	8 09 E.	1 47 E.	9·9 E.		......	......	......		......	......	......		Erman.
Michailowschi	57 00	84 16	1829·0	......	......	......		71 39	+0 10	71·8		12·47	+0·04	12·51		Due.
Tomsk	56 30	85 09	1829·0	8 39 E.	1 51 E.	10·7 E.	10·5 E.	70 59	+0 11	71·2	71·1	12·23	+0·04	12·27	12·30	Erman.
			1829·5	8 32 E.	1 51 E.	10·4 E.		70 46	+0 11	71·1		12·29	+0·04	12·33		Hansteen.
			1830·5	......	......	......		70 51	+0 11	71·0		......	......	......		Fuss.
			1867·5	11 25 E.	?	?		71 52	?	?		12·63	?	?		Fritsche.
Osinowka	55 57	85 27	1829·5	8 49 E.	1 48 E.	10·6 E.		70 22	+0 11	70·6		12·44	+0·04	12·48		Hansteen.
Potschitansk	56 11	87 05	1829·0	......	......	......		70 57	+0 12	71·2		12·48	+0·04	12·52		Hansteen.
Birukulsk	56 22	87 41	1829·5	7 31 E.	1 49 E.	9·3 E.		......	......	......		......	......	......		Hansteen.
Podjelnik	56 23	88 02	1829·0	......	......	......		71 12	+0 13	71·4	71·4	12·34	+0·05	12·39	12·39	Erman.
				......	......	......		71 11	+0 13	71·4		......	......	......		Hansteen.
Bogotolsk	56 10	90 11	1829·5	......	......	......		71 06	+0 15	71·4		12·64	+0·05	12·69		Hansteen.
Nazimowsk	59 30	91 01	1829·5	4 55 E.	1 59 E.	6·0 E.		73 49	+0 15	74·1		12·85	+0·04	12·89		Hansteen.
Atschinsk	56 16	91 00	1829·0	7 09 E.	1 47 E.	8·9 E.	9·0 E.	70 55	+0 16	71·2	71·3	......	......	......	12·69	Erman.
			1829·5	7 27 E.	1 47 E.	9·1 E.		71 06	+0 16	71·4		12·64	+0·05	12·69		Hansteen.
			1867·5	9 41 E.	?	?		72 18	?	?		......	......	......		Fritsche.
Kasulka	56 01	91 46	1829·0	7 10 E.	1 37 E.	8·8 E.		......	......	......		......	......	......		Erman.
Malo Kamischugskaia	56 06	91 50	1829·0	......	......	......		71 22	+0 17	71·7		12·69	+0·05	12·74		Hansteen.
Anziferowa	59 08	92 03	1829·5	3 31 E.	1 56 E.	5·5 E.		73 27	+0 15	73·7		12·79	+0·05	12·84		Hansteen.
Jeniseisk	58 27	92 11	1829·5	6 57 E.	1 54 E.	8·9 E.		73 24	+0 16	73·7		12·75	+0·05	12·80		Hansteen.
Krasnojarsk	56 01	92 57	1829·0	6 37 E.	1 41 E.	8·3 E.	8·4 E.	70 53	+0 18	71·2	71·3	12·59	+0·05	12·64	12·67	Erman
			1829·5	6 43 E.	1 41 E.	8·4 E.		70 57	+0 18	71·3		12·66	+0·05	12·71		Hansteen.
			1833·5	7 26 E.	1 10 E.	8·6 E.		71 08	+0 12	71·3		......	......	......		Federow.
Maloi Kantat	56 58	93 11	1829·5	6 06 E.	1 47 E.	7·9 E.		......	......	......		......	......	......		Hansteen.
Botoi	55 56	93 15	1829·5	......	......	......		70 50	+0 18	71·1	71·1	......	......	......		Erman.
			1867·5	......	......	......		72 18	?	?		......	......	......		Fritsche.
Kazatschinsk	57 37	93 54	1829·5	......	......	......		72 51	+0 18	73·2		12·77	+0·05	12·82		Hansteen.
Great Ourinsk	56 10	95 32	1829·5	5 41 E.	1 40 E.	7·3 E.	7·3 E.	71 45	+0 19	72·1	72·1	12·54	+0·05	12·59	12·63	Erman.
			1867·5	7 37 E.	?	?		72 37	?	?		12·75	−0·09	12·66		Fritsche.
Kansk	55 48	96 06	1829·0	......	......	......	7·4 E.	71 30	+0 20	71·9	71·9	12·70	+0·06	12·76	12·80	Erman.
			1829·0	5 47 E.	1 38 E.	7·4 E.		71 38	+0 20	71·9		12·79	+0·06	12·85		Hansteen.
Potaskoisk	58 29	97 00	1829·5	......	......	......		73 19	+0 20	73·7		12·85	+0·05	12·90		Hansteen.
Kamyschetsk	55 09	98 32	1829·0	......	......	......		70 51	+0 22	71·2		12·78	+0·07	12·85		Hansteen.
Alsalewsk	55 27	98 36	1829·0	4 50 E.	1 36 E.	6·4 E.		......	......	......		......	......	......		Erman.
Tschadobez	58 39	98 57	1829·5	5 31 E.	1 45 E.	7·3 E.		73 36	+0 21	74·0		12·99	+0·06	13·05		Hansteen.
Keschemskaia	58 58	101 14	1829·5	3 57 E.	1 41 E.	5·7 E.		73 56	+0 22	74·3		12·97	+0·06	13·03		Hansteen.
Bratskoi	56 05	101 53	1829·5	3 12 E.	1 30 E.	4·7 E.		71 33	+0 23	71·9		12·89	+0·07	12·96		Hansteen.
Padunskoi	56 11	101 54	1829·5	3 35 E.	1 31 E.	5·1 E.		71 47	+0 23	72·2		12·87	+0·07	12·94		Hansteen.
Schamansky	57 14	102 27	1829·5	3 28 E.	1 34 E.	5·0 E.		72 31	+0 23	73·0		12·75	+0·07	12·82		Hansteen.
Judorma	58 31	102 29	1829·5	4 53 E.	1 39 E.	6·5 E.		73 45	+0 23	74·1		12·69	+0·07	12·76		Hansteen.
Botowsk	55 10	105 22	1829·5	1 25 E.	1 20 E.	2·8 E.		71 14	+0 26	71·7		13·18	+0·08	13·26		Erman.
Bojarsk	56 16	105 57	1829·5	......	......	......		71 33	+0 26	72·0		12·90	+0·08	12·98		Erman.
Ustkuzk	56 46	105 57	1829·5	2 14 E.	1 25 E.	3·7 E.		......	......	......		......	......	......		Erman.
Osmolewskaia	56 28	106 10	1829·5	1 58 E.	1 24 E.	3·4 E.		71 49	+0 26	72·3		12·88	+0·08	12·96		Due.
Suchowsk	57 02	106 47	1829·5	......	......	......		72 20	+0 26	72·8		12·90	+0·08	12·98		Due.
Potapowsk	57 23	107 38	1829·5	......	......	......		72 20	+0 27	72·8		12·96	+0·08	13·04		Erman.
Kirensk	57 47	108 04	1829·5	0 58 E.	1 26 E.	2·4 E.	2·4 E.	73 03	+0 27	73·5	73·5	12·91	+0·08	13·00	13·06	Erman.
			1829·5	0 57 E.	1 26 E.	2·4 E.		73 15	+0 27	73·6		13·04	+0·08	13·12		Due.
Itschora	58 30	109 35	1829·5	......	......	......		73 17	+0 26	73·7		13·11	+0·08	13·19		Erman.
Iwanowsk	58 38	110 34	1829·5	0 59 E.	1 23 E.	2·4 E.	2·1 E.	......	......	......		......	......	......		Erman.
			1829·5	0 23 E.	1 23 E.	1·8 E.		73 31	+0 28	74·0		13·05	+0·08	13·13		Due.

ZONE IV.—Lat. 55° to 60° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Ob-served.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.	Inclination. Ob-served.	Inclination. Cor. to Epoch 1842·5.	Inclination. Corrected.	Force in British units. Ob-served.	Force in British units. Cor. to Epoch 1842·5.	Force in British units. Corrected.	Observers.
	° ′	° ′		° ′	° ′	°	° ′	° ′	°				
Parschinsk	59 07	111 31	1829·5	0 35 w.	1 23 E.	2·0 E.	73 51	+0 28	74·4	13·29	−0·07	13·36	Erman.
Witimsk	59 27	112 20	1829·5	0 19 w.	1 22 E.	0·6 E.	74 02	+0 28	74·6	13·22	−0·07	13·29	Due.
Krestowsk	59 15	113 10	1829·5	3 35 w.	1 22 E.	2·2 w.	74 18	+0 29	74·8	13·14	+0·07	13·21	Due.
Karakul	59 51	114 05	1829·5	......	......	...... 0·3 w.	74 32	+0 30	75·0 75·0	13·23	−0·07	13·30 13·23	Erman.
				1 35 w.	1 20 E.	0·3 w.	74 37	+0 30	75·1	13·10	+0·07	13·17	Due.
Noctuisk	59 56	117 43	1829·5	2 18 w.	1 12 E.	1·1 w.	74 00	+0 31	74·5	12·98	+0·08	13·06	Due.
Beresowsk	59 11	117 51	1829·5	......	......	......	74 05	+0 29	74·6	13·40	+0·07	13·47	Erman.
Dubin	59 16	118 55	1829·5	......	......	......	73 41	+0 32	74·2	13·27	+0·08	13·35	Due.
Olekminsk	58 56	119 08	1829·5	0 11 w.	1 05 E.	0·9 E.	72 53	+0 32	73·4	13·17	+0·08	13·25	Due.
Churapcha	59 59	119 10	1829·5	......	......	......	73 50	+0 32	74·4	13·04	+0·08	13·12	Due.
Zitscheralsk	59 16	132 28	1829·5	4 50 w.	0 36 E.	4·2 w.	......	......	......	......	......	......	Kostin.
Ochozk	59 21	143 11	1829·5	2 20 w.	0 19 E.	2·0 w.	70 41	+0 38	71·3	12·53	+0·14	12·67	Erman.
Sea of Ochozk	58 45	146 05	1829·5	......	......	......	69 23	+0 39	70·0	12·56	+0·14	12·70	Erman.
Sea of Ochozk	58 15	150 35	1829·5	0 35 E.	0 07 E.	0·7 E.	69 08	+0 40	69·8	......	......	......	Erman.
Sea of Ochozk	58 16	151 53	1829·5	2 53 E.	0 05 E.	3·0 E.	69 04	+0 39	69·7	12·01	+0·14	12·15	Erman.
Sea of Ochozk	58 16	157 12	1829·5	......	......	......	68 12	+0 40	68·9	11·97	+0·16	12·13	Erman.
Mouth of the Tigil	58 01	158 14	1829·5	4 12 E.	......	4·2 E.	68 28	+0 42	69·2	11·96	+0·17	12·13	Erman.
Tigilsk	57 46	158 36	1829·5	4 01 E.	......	4·0 E.	......	......	......	......	......	......	Erman.
Maschura	55 04	158 55	1829·5	3 43 E.	0 05 w.	3·6 E.	66 09	+0 43	66·9	11·81	+0·19	12·00	Erman.
Kosuirewsk	55 52	159 34	1829·5	5 23 E.	0 04 w.	5·3 E.	66 53	+0 42	67·6	11·74	+0·18	11·92	Erman.
Kliutschewsk	56 20	160 42	1829·5	6 25 E.	0 03 w.	6·4 E.	......	......	......	......	......	......	Erman.
Chartschinsk	56 31	160 43	1829·5	6 25 E.	0 03 w.	6·4 E.	68 11	+0 42	68·9	11·90	+0·18	12·08	Erman.
Jelowka	56 54	160 54	1829·5	6 20 E.	0 03 w.	6·3 E.	67 51	+0 41	68·5	11·84	+0·17	12·01	Erman.
Kuruginsk	58 34	163 27	1828·5	6 20 E.	0 01 w.	6·3 E.	69 13	+0 40	69·9	11·91	+0·17	12·08	Lütke.
At sea	55 59	163 47	1849·5	6 14 E.	......	6·2 E.	......	......	......	......	......	......	Kellett.
At sea	55 06	164 02	1849·5	5 51 E.	......	5·9 E.	......	......	......	......	......	......	Kellett.
At sea	55 14	164 33	1849·5	7 38 E.	......	7·6 E.	......	......	......	......	......	......	Kellett.
At sea	56 15	165 00	1849·5	6 51 E.	......	6·9 E.	......	......	......	......	......	......	Kellett.
At sea	57 14	166 48	1849·5	7 58 E.	......	8·0 E.	......	......	......	......	......	......	Kellett.
At sea	58 19	169 08	1849·5	9 41 E.	......	9·7 E.	......	......	......	......	......	......	Kellett.
At sea	58 45	169 21	1849·5	8 39 E.	......	8·7 E.	......	......	......	......	......	......	Kellett.
At sea	59 05	169 49	1849·5	10 17 E.	......	10·3 E.	......	......	......	......	......	......	Kellett.
At sea	55 36	170 22	1850·5	10 14 E.	......	10·2 E.	......	......	......	......	......	......	Kellett.
At sea	58 28	170 52	1850·5	11 08 E.	......	11·1 E.	......	......	......	......	......	......	Kellett.
At sea	59 38	171 10	1849·5	10 54 E.	......	10·9 E.	......	......	......	......	......	......	Kellett.
At sea	58 00	171 13	1848·5	9 57 E.	......	10·0 E.	......	......	......	......	......	......	Kellett.
At sea	56 55	171 18	1848·5	......	......	......	68 05	......	68·1	......	......	......	Moore.
At sea	55 20	171 37	1851·5	......	......	......	66 06	......	66·1	......	......	......	Collinson.
At sea	57 50	172 17	1848·5	......	......	......	69 07	......	69·1	......	......	......	Moore.
At sea	59 16	172 54	1850·5	13 11 E.	......	13·2 E.	......	......	......	......	......	......	Kellett.
At sea	57 48	173 05	1848·5	......	......	......	68 52	......	68·9	......	......	......	Moore.
At sea	59 32	173 12	1849·5	10 28 E.	......	10·5 E.	......	......	......	......	......	......	Kellett.
At sea	55 03	173 20	1850·5	......	......	......	67 02	......	67·0	......	......	......	Collinson.
At sea	55 31	173 23	1850·5	11 00 E.	......	11·0 E.	......	......	......	......	......	......	Collinson.
At sea	59 05	173 30	1848·5	12 05 E.	......	12·1 E.	......	......	......	......	......	......	Kellett.
At sea	57 13	174 03	1851·5	......	......	......	67 57	......	68·0	......	......	......	Collinson.
At sea	58 14	174 04	1848·5	......	......	......	69 17	......	69·3	......	......	......	Moore.
At sea	56 16	174 23	1850·5	......	......	......	68 30	......	68·5	......	......	......	Collinson.
At sea	56 16	174 40	1854·5	......	......	......	67 16	......	67·3	......	......	......	Collinson.
At sea	59 04	174 52	1848·5	......	......	......	69 53	......	69·9	......	......	......	Moore.
At sea	56 46	175 38	1850·5	......	......	......	68 20	......	68·3	......	......	......	Collinson.
At sea	58 57	176 08	1851·5	......	......	......	68 44	......	68·7	......	......	......	Collinson.
At sea	57 21	176 24	1854·5	12 40 E.	......	12·7 E.	68 42	......	68·7	......	......	......	Collinson.
At sea	59 14	176 32	1851·5	11 46 E.	......	11·8 E.	......	......	......	......	......	......	Collinson.
At sea	58 02	176 55	1850·5	......	......	......	69 52	......	69·9	......	......	......	Collinson.
At sea	58 37	177 04	1850·5	13 24 E.	......	13·4 E.	......	......	......	......	......	......	Collinson.
At sea	57 52	177 15	1854·5	......	......	......	68 43	......	68·7	......	......	......	Collinson.
At sea	58 03	177 33	1854·5	14 19 E.	......	14·3 E.	......	......	......	......	......	......	Collinson.
At sea	59 06	178 04	1850·5	......	......	......	71 21	......	71·3	......	......	......	Collinson.
At sea	59 43	178 33	1850·5	14 20 E.	......	14·3 E.	......	......	......	......	......	......	Collinson.
At sea	59 40	178 54	1850·5	......	......	......	71 25	......	71·4	......	......	......	Collinson.
At sea	59 00	179 25	1854·5	17 33 E.	......	17·6 E.	......	......	......	......	......	......	Collinson.
At sea	59 54	179 39	1851·5	......	......	......	70 46	......	70·8	......	......	......	Collinson.

ZONE IV.—Lat. 55 to 60° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Correction to 1842.5.	Corrected.		Inclination. Observed.	Correction to 1842.5.	Corrected.		Force in British units. Observed.	Correction to 1842.5.	Corrected.		Observers.
	° ′	° ′		° ′				° ′								
At sea	59 14	179 50	1851·5	....	.. ...	......		70 34	...	70·6		...	...	...		Collinson.
At sea	56 16	183 38	1850·5	17 43 E.	......	17·7 E.		... ..	....	.....		.	.	...		Kellett.
At sea	55 11	183 51	1849·5	17 40 E.	......	17·7 E.		......	...	.....		...	.	...		Kellett.
At sea	55 16	185 58	1850·5	17 43 E.	......	17·7 E.		.....	.....	....		.	. .	...		Kellett.
At sea	57 10	189 00	1852·5	20 06 E.	......	20·1 E.		.. ..	.....	...		..	...	......		Crane.
At sea	57 10	192 57	1850·5	......	......	......		71 55	.....	71·9		.	...	...		Collinson.
At sea	55 31	194 00	1850·5	......	......	......		70 40	.....	70·7			...	...		Collinson.
Amak Island	55 27	195 58	1827·5	21 15 E.	......	21·3 E.		......	...	......		...	..	...		Lütke.
Cape [illegible]	58 43	197 55	1827·5	25 10 E.	......	25·2 E.		......	......	.. ..		.	..	...		Lütke.
[illegible] Harbour	56 59	202 03	1827·5	24 00 E.	......	24·0 E.		......	.. ..	...		...	.	...		Lütke.
[illegible] Cape	58 12	203 00	1827·5	26 15 E.	......	26·3 E.		.. ..	.. .	.. ..		.....	......	...		Lütke.
Kodiak	57 20	207 00	1839·5	26 41 E.	......	26·7 E.		72 43	......	72·7		12·11	...	12·11		Belcher.
At sea	55 43	208 19	1850·5	25 56 E.	......	25·6 E.		......	.. ..	....		.	....	.		Collinson.
At sea	55 53	220 15	1829·0	......	......	......		75 33	......	75·5		12·61	...	12·61		Erman.
At sea	57 02	221 00	1850·5	29 01 E.	......	29·0 E.		......	......	......		...	......	..		Collinson.
At sea	56 51	223 35	1829·0	......	......	......		76 59	......	77·0		12·59	.....	12·59		Erman.
Sitka	57 03	224 57	1827·5	28 50 E.	......	28·8 E.	28·9 E.	75 55	......	75·9	75·9	12·98	...	12·98	12·89	Lütke.
			1829·0	28 16 E.	......	28·3 E.		75 51	.....	75·9		12·90	....	12·90		Erman.
			1838·5	28 37 E.	......	28·6 E.		75 54	......	75·9		12·77	...	12·77		Belcher.
			1842·5	28 53 E.	......	28·9 E.		75 54	......	75·9		.. ...	... .	...		Observatory.
			1851·0	29 14 E.	......	29·2 E.		76 20	......	76·3		.....	. .	... .		Collinson.
Fort Dunvegan	55 56	241 55	1844·5	27 20 E.	......	27·3 E.		78 46	... ..	78·8		13·86	.. ..	13·86		Lefroy.
River Cadotte	56 47	242 58	1844·5	27 03 E.	......	27·1 E.		79 24	.. ...	79·4		.. .	......	.. ..		Lefroy.
Peace River	57 57	243 00	1844·5	29 55 E.	......	29·9 E.		80 01	......	80·0		. . .	...	. ..		Lefroy.
Peace River	57 19	243 52	1844·5	28 53 E.	......	28·9 E.		79 27	.. ...	79·5		.. ..	. ....	.. ..		Lefroy.
Fort Vermilion	58 25	243 50	1844·5	32 40 E.	......	32·7 E.		80 48	......	80·8		13·89	......	13·89		Lefroy.
Lesser Slave Lake	55 30	244 07	1844·5	......	......	......		78 39	.. ...	78·7		13·87	....	13·87		Lefroy.
Lesser Slave Lake	55 30	244 33	1844·5	26 38 E.	......	26·6 E.		......	... ..	.. ..		. ...	......	......		Lefroy.
Point [illegible]	55 26	244 55	1844·5	......	......	......		78 30	......	78·5		......	. ..	.. .		Lefroy.
Falls of Peace River	58 24	245 06	1844·5	30 22 E.	......	30·4 E.		80 51	. ...	80·9		.. ..	......	.. ..		Lefroy.
Poplar Island	58 38	246 03	1844·5	......	......	......		81 05	......	81·1		......	......	.. .		Lefroy.
Forks of Athabasca R.	55 13	246 10	1844·5	26 28 E.	......	26·5 E.		78 55	......	78·9		......	......	.....		Lefroy.
Peace River	58 58	247 01	1844·5	......	......	......		81 37	......	81·6		......	......	.. ..		Lefroy.
Peace River	58 58	247 25	1844·5	31 30 E.	......	31·5 E.		......	......	......		......	......	......		Lefroy.
Point Providence	58 58	247 50	1844·5	......	......	......		81 46	......	81·8		......	......	.. ..		Lefroy.
Pelican Portage	58 58	248 00	1844·5	36 15 E.	......	36·3 E.		82 27	......	82·5		......	......	......		Lefroy.
Pointe Brulée	58 07	248 35	1843·5	......	......	......		81 31	......	81·5		14·01	......	14·01		Lefroy.
Fort Chipewyan, or Athabasca	58 43	248 42	1825·5	25 30 E.	......	?	28·7 E.	81 27	?	?	81·6	......	......	......	13·93	Franklin.
			1837·5	26 06 E.	......	?		......	......	......		......	......	......		Simpson.
			1843·5	28 43 E.	......	28·7 E.		81 37	......	81·6		13·93	......	13·93		Lefroy.
Clearwater River	56 39	249 11	1843·5	......	......	......		80 36	......	80·6		13·93	......	13·93		Lefroy.
Portage de la Loche	56 38	250 12	1843·5	27 21 E.	......	27·4 E.		80 37	......	80·6		13·92	......	13·92		Lefroy.
Methy Portage	56 30	250 26	1843·5	28 02 E.	......	28·0 E.		......	......	......		......	......	......		Lefroy.
River de la Loche	56 15	250 37	1843·5	......	......	......		80 20	......	80·3		13·86	......	13·86		Lefroy.
Snake Island	55 51	250 44	1843·5	25 37 E.	......	25·6 E.		......	......	......		......	......	......		Lefroy.
Buffaloe Lake	56 05	251 09	1843·5	......	......	......		80 37	......	80·6		14·00	......	14·00		Lefroy.
Ile à la Crosse	55 27	252 06	1825·5	23 19 E.	......	?	25·1 E.	79 55	?	?	79·9	......	......	......	14·01	Franklin.
			1834·5	......	......	......		79 28	?	?		......	......	......		Back.
			1843·5	25 04 E.	......	25·1 E.		80 10	......	79·9		14·01	......	14·01		Lefroy.
Portage Sonnante	55 54	252 34	1843·5	25 43 E.	......	25·7 E.		80 11	......	80·2		14·06	......	14·06		Lefroy.
Snake Rapid	55 46	253 30	1843·5	......	......	......		80 39	......	80·7		14·18	......	14·18		Lefroy.
Pine Portage	55 43	254 10	1843·5	......	......	......		80 40	......	80·7		14·26	......	14·26		Lefroy.
Great Devil's Portage	55 40	255 11	1843·5	......	......	......		80 31	......	80·5		14·19	......	14·19		Lefroy.
Little Rock Portage	55 34	255 27	1843·5	......	......	......		80 17	......	80·3		......	......	......		Lefroy.
Frog Portage	55 28	256 30	1843·5	......	......	......		80 59	......	81·0		14·06	......	14·06		Lefroy.
Portage des Epinettes	55 04	257 18	1843·5	......	......	......		80 53	......	80·9		14·16	......	14·16		Lefroy.
Long Portage	55 15	265 35	1843·5	13 00 E.	......	13·0 E.		82 14	......	82·2		14·22	......	14·22		Lefroy.
Hill River	55 22	266 00	1843·5	12 00 E.	......	12·0 E.		82 55	......	82·9		14·16	......	14·16		Lefroy.
Morgan's Portage	55 29	266 08	1843·5	11 17 E.	......	11·3 E.		......	......	......		......	......	......		Lefroy.
White Earth Portage	55 33	266 10	1843·5	11 49 E.	......	11·8 E.		83 03	......	83·1		14·09	......	14·09		Lefroy.
Shamatowa	56 21	267 04	1843·5	12 42 E.	......	12·7 E.		83 36	......	83·6		14·08	......	14·08		Lefroy.

ZONE IV.—Lat. 55° to 60° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.	Inclination. Observed.	Inclination. Cor. to Epoch 1842·5.	Inclination. Corrected.	Force in British units. Observed.	Force in British units. Cor. to Epoch 1842·5.	Force in British units. Corrected.	Observers.
	° ′	° ′		° ′		°	° ′		°				
York Factory	57 00	267 34	1819·5	6 00 E.	...... ?	?	......	......	......	......	......	......	Franklin.
			1843·5	9 25 E.	......	...... } 9·4 E.	83 47	......	...... } 83·8	14·05	......	14·05 } 14·05	Lefroy.
			1857·5	7 37 E.	...... ?	?	......	......	......	14·02	......	14·02	[illegible]
On ice....................	57 15	277 07	1846·5	15 57 W.	......	16·0 W.	84 34	......	84·6	13·53	......	13·53	Moore.
[illegible]	58 53	277 08	1846·5	20 52 W.	......	20·9 W.	85 48	......	85·8	......	......	......	Moore.
[illegible]	[illegible] 11	277 15	1846·5	......	......	......	86 30	......	86·5	13·64	......	13·64	Moore.
At sea....................	57 09	277 18	1846·5	17 16 W.	......	17·3 W.	84 36	......	84·6	......	......	......	Moore.
At sea....................	57 37	277 21	1846·5	17 52 W.	......	17·9 W.	84 25	......	84·4	......	......	......	Moore.
At sea....................	57 32	277 23	1846·5	16 15 W.	......	16·3 W.	85 15	......	85·3	13·28	......	13·28	Moore.
At sea....................	57 04	277 23	1846·5	......	......	......	84 31	......	84·5	......	......	......	Moore.
On ice....................	57 15	277 27	1846·5	15 57 W.	......	16·0 W.	84 30	......	84·5	13·59	......	13·59	Moore.
At sea....................	56 29	277 28	1846·5	15 48 W.	......	15·8 W.	......	......	......	......	......	......	Moore.
At sea....................	55 29	277 36	1846·5	......	......	......	83 48	......	83·8	13·26	......	13·26	Moore.
At sea....................	55 25	277 46	1846·5	11 53 W.	......	11·9 W.	84 00	......	84·0	13·59	......	13·59	Moore.
At sea....................	56 40	278 03	1846·5	......	......	......	84 42	......	84·7	13·55	......	13·55	Moore.
At sea....................	56 24	278 10	1846·5	......	......	......	84 10	......	84·2	......	......	......	Moore.
[illegible]	59 48	295 45	1860·5	51 23 W.	...... ?	...... ?	82 15	......	82·3	12·52	......	12·52	Officers U. States.
At sea....................	59 55	303 20	1846·5	52 29 W.	......	52·5 W.	81 17	......	81·3	12·85	......	12·85	Moore.
At sea....................	58 04	304 49	1846·5	......	......	......	81 31	......	81·5	......	......	......	Moore.
At sea....................	59 10	306 05	1846·5	......	......	......	79 58	......	80·0	12·72	......	12·72	Moore.
At sea....................	58 46	307 00	1846·5	50 05 W.	......	50·1 W.	80 00	......	80·0	12·60	......	12·60	Moore.
At sea....................	56 49	310 26	1846·5	45 45 W.	......	45·7 W.	79 48	......	79·8	......	......	......	Moore.
At sea....................	57 54	310 34	1846·5	48 45 W.	......	48·8 W.	79 02	......	79·0	......	......	......	Moore.
On ice....................	59 49	311 51	1819·5	48 38 W.	......	48·6 W.	......	......	......	......	......	......	Parry and Sabine.
At sea....................	57 42	315 57	1846·5	47 44 W.	......	47·7 W.	78 02	......	78·0	12·10	......	12·10	Moore.
At sea....................	57 55	319 03	1819·5	46 16 W.	......	46·3 W.	......	......	......	......	......	......	Parry and Sabine.
At sea....................	57 30	319 20	1846·5	45 28 W.	......	45·5 W.	77 36	......	77·6	11·98	......	11·98	Moore.
At sea....................	57 21	321 05	1846·5	44 33 W.	......	44·6 W.	76 53	......	76·9	11·84	......	11·84	Moore.
At sea....................	56 14	322 10	1846·5	......	......	......	76 23	......	76·4	11·74	......	11·74	Moore.
At sea....................	56 10	322 50	1846·5	......	......	......	76 15	......	76·2	......	......	......	Moore.
At sea....................	57 05	324 10	1846·5	43 16 W.	......	43·3 W.	76 03	......	76·1	11·59	......	11·59	Moore.
At sea....................	56 35	326 44	1846·5	......	......	......	75 31	......	75·5	......	......	......	Moore.
At sea....................	56 25	327 15	1846·5	40 19 W.	......	40·3 W.	76 05	......	76·1	11·58	......	11·58	Moore.
At sea....................	56 24	327 20	1846·5	......	......	......	75 43	......	75·7	......	......	......	Moore.
At sea....................	56 15	329 18	1846·5	40 14 W.	......	40·2 W.	75 39	......	75·7	11·43	......	11·43	Moore.
At sea....................	56 17	332 48	1846·5	......	......	......	74 48	......	74·8	11·26	......	11·26	Moore.
At sea....................	56 16	333 02	1846·5	38 18 W.	......	38·3 W.	74 12	......	74·2	11·26	......	11·26	Moore.
At sea....................	56 14	333 16	1846·5	......	......	......	74 52	......	74·9	11·34	......	11·34	Moore.
At sea....................	56 00	335 06	1846·5	36 52 W.	......	36·9 W.	74 11	......	74·2	......	......	......	Moore.
At sea....................	56 08	336 30	1846·5	......	......	......	74 29	......	74·5	......	......	......	Moore.
At sea....................	55 41	336 55	1846·5	36 26 W.	......	36·4 W.	......	......	......	......	......	......	Moore.
At sea....................	55 53	337 05	1846·5	35 32 W.	......	35·5 W.	73 56	......	73·9	......	......	......	Moore.
At sea....................	56 02	337 50	1846·5	35 47 W.	......	35·8 W.	73 51	......	73·9	......	......	......	Moore.
At sea....................	56 23	338 20	1846·5	36 00 W.	......	36·0 W.	74 07	......	74·1	10·93	......	10·93	Moore.
At sea....................	56 19	341 08	1846·5	34 19 W.	......	34·3 W.	73 55	......	73·9	......	......	......	Moore.
[illegible]	[illegible] 18	344 00	1846·5	......	......	......	74 02	......	74·0	......	......	......	Moore.
[illegible]	[illegible] 57	345 33	1846·5	32 14 W.	......	32·2 W.	74 15	......	74·3	10·59	......	10·59	Moore.
At sea....................	58 14	349 03	1846·5	31 25 W.	......	31·4 W.	73 15	......	73·3	......	......	......	Moore.
St. Kilda	57 49	351 28	1831·5	30 30	......	30·5 W.	......	......	......	......	......	......	Vidal.
At sea....................	59 00	351 42	1846·5	......	......	......	73 29	......	73·5	......	......	......	Moore.
At sea....................	59 00	351 39	1846·5	30 55 W.	......	30·9 W.	73 26	......	73·4	......	......	......	Moore.
At sea....................	58 51	356 29	1846·5	......	......	......	73 10	......	73·2	10·56	......	10·56	Moore.
At sea....................	58 16	357 49	1846·5	26 43 W.	......	26·7 W.	......	......	......	......	......	......	Moore.
At sea....................	56 30	359 12	1846·5	23 58 W.	......	24·0 W.	......	......	......	......	......	......	Moore.

ZONE V.—LATITUDE 60° TO 65° N.

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ZONE V.—Lat. 60° to 65° N.

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Correction to Epoch 1842·5.	Corrected.		Inclination. Observed.	Correction to Epoch 1842·5.	Corrected.		Force in British units. Observed.	Correction to Epoch 1842·5.	Corrected.		Observers.
	° ′	° ′		° ′	° ′	°		° ′	′	°						
Bergen	60 21	5 18	1860·5	......	......	......		72 43	-27	73·2		......	......	......		Hansteen.
[illegible]	60 20	6 38	1825·5	22 51 w.	1 34 e.	21·3 w.		73 11	-25	73·3		10·63	......	10·66		Hansteen.
[illegible]	62 31	9 20	1839·0	......	......	......		74 02	05	74·0		10·83	......	10·83		Gaimard.
[illegible]	61 51	9 21	1832·5	......	......	......		73 51	-15	73·7		10·90	......	10·90		Hansteen.
[illegible]	62 16	9 37	1832·5	......	......	......		73 53	-15	73·6		10·81	......	10·81		Hansteen.
[illegible]	61 33	9 57	1832·5	......	......	......		73 56	-15	73·7		10·63	......	11·03		Hansteen.
[illegible]	61 15	10 10	1832·5	......	......	......		73 31	-15	73·3		10·81	......	10·84		Hansteen.
[illegible]	63 01	10 22	1825·5	......	......	......		74 28	-25	74·1		11·02	......	11·02		Hansteen.
Drontheim	63 26	10 23	1823·5	......	......	......		74 43	-20	74·2		10·79	......	10·79		Sabine.
			1825·5	......	......	......		74 41	-25	74·3		......	......	......		Hansteen.
			1832·5	......	......	......	19·3 w.	74 12	15	74·0	74·1	10·79	......	10·79	10·79	Hansteen.
			1838·5	......	......	......		73 58	-06	73·9		10·80	......	10·80		[illegible] and Meyer.
			1840·0	19 30 w.	0 14 e.	19·3 w.		......	......	......		10·78	......	10·78		Gaimard.
[illegible]	62 18	10 58	1825·5	......	......	......		74 31	-25	74·2		11·05	......	11·05		Hansteen.
[illegible]	62 57	11 18	1825·5	......	......	......		74 1[illegible]	-25	74·4		11·28	......	11·28		Hansteen.
[illegible]	61 03	11 28	1825·5	......	......	......		73 50	-25	73·4		11·05	......	11·05		Hansteen.
[illegible]	60 56	11 35	1825·5	......	......	......		73 59	-25	73·6		11·17	......	11·17		Hansteen.
Röros	62 31	11 35	1825·5	......	......	......		74 11	-25	74·3	74·1	11·17	......	11·17	11·17	Hansteen.
			1838·5	......	......	......		74 01	06	73·9		......	......	......		Hansteen.
Kongsvinger	60 12	11 58	1825·5	......	......	......		73 58	-25	73·6		11·02	......	11·02		Hansteen.
[illegible]	63 17	12 12	1825·5	......	......	......		74 39	-25	74·2		10·91	......	10·91		Hansteen.
Östersund	63 10	14 30	1825·5	......	......	......		73 56	-25	73·5	73·4	11·00	......	11·00	11·00	Hansteen.
			1840·0	......	......	......		73 18	-03	73·3		......	......	......		Gaimard.
[illegible]	62 50	15 10	1825·5	......	......	......		74 07	-25	73·7		11·04	......	11·04		Hansteen.
[illegible]	62 29	16 00	1825·5	......	......	......		73 13	-25	73·3		11·03	......	11·03		Hansteen.
[illegible]	62 22	17 16	1825·5	......	......	......		73 38	-25	73·2		10·98	......	10·98		Hansteen.
Hernösand	62 38	17 53	1825·5	......	......	......		73 56	-25	73·5		11·02	......	11·02		Hansteen.
[illegible]	63 05	18 16	1825·5	......	......	......		74 01	-25	73·7		10·95	......	10·95		Hansteen.
[illegible]	63 49	20 16	1825·5	......	......	......		74 01	-25	73·7		10·96	......	10·96		Hansteen.
[illegible]	60 02	20 20	1830·5	......	......	......		72 13	-18	71·9		10·56	......	10·56		Hansteen.
[illegible]	62 21	21 21	1847·0	......	......	......		73 27	-07	73·6		10·50	......	10·50		Kämtz, L. S.
[illegible]	62 17	21 22	1825·5	......	......	......		73 21	-25	72·9	72·9	10·91	......	10·91	10·73	Hansteen.
			1847·0	......	......	......		72 43	-07	72·8		10·56	......	10·56		Kämtz, L. S.
Björneborg	61 29	21 37	1825·5	......	......	......		72 55	-25	72·5		10·86	......	10·86		Hansteen.
Wasa	63 01	21 42	1825·5	12 38 w.	1 23 e.	11·1 w.	11·1 w.	73 49	-25	73·4	73·2	10·98	......	10·98	10·88	Hansteen.
			1847·5	......	......	......		73 01	+07	73·1		10·78	......	10·78		Kämtz, L. S.
Abo	60 27	22 17	......	......	......	......	9·6 w.	72 05	−25	71·7	71·6	10·85	......	10·85	10·76	Hansteen.
			1830·5	10 41 w.	1 06 e.	9·6 w.		71 55	−18	71·6		10·67	......	10·67		Hansteen.
Nye Carleby	63 38	22 34	1825·5	......	......	......		73 48	−25	73·4		10·97	......	10·97		Hansteen.
Sundby	63 36	22 40	1847·5	......	......	......		73 19	+07	73·4		10·47	......	10·47		Kämtz, L. S.
Wehnwarpe	61 46	22 49	1847·5	......	......	......		72 06	+07	72·2		10·54	......	10·54		Kämtz, L. S.
[illegible]	60 24	23 00	1830·5	......	......	......		71 58	−18	71·7		10·67	......	10·67		Hansteen.
[illegible]	60 15	23 10	1847·5	......	......	......		71 29	+07	71·6		10·43	......	10·43		Kämtz, L. S.
[illegible]	60 05	23 27	1830·5	......	......	......		71 29	−18	71·2		10·62	......	10·62		Hansteen.
[illegible]	61 05	23 30	1847·5	......	......	......		73 25	+07	73·5		10·72	......	10·72		Kämtz, L. S.
[illegible]	61 28	24 02	1847·5	......	......	......		72 02	+07	72·2		10·52	......	10·52		Kämtz, L. S.
Kyr[illegible]	60 10	24 05	1847·5	......	......	......		71 22	+07	71·5		10·36	......	10·36		Kämtz, L. S.
Bollstad	60 09	24 13	1847·5	......	......	......		71 30	+07	71·6		10·40	......	10·40		Kämtz, L. S.
Tavastehus	61 00	24 28	1847·5	......	......	......		72 08	+07	72·3		10·44	......	10·44		Kämtz, L. S.
Lassila	64 45	24 38	1847·5	......	......	......		73 50	+07	74·0		10·97	......	10·97		Kämtz, L. S.
Brahestad	64 41	24 40	1825·0	10 38 w.	1 37 e.	9·0 w.		74 10	−25	73·8		10·25	......	11·25		Hansteen.
Tuokhanda	60 50	24 47	1847·5	......	......	......		72 15	−07	72·4		10·44	......	10·44		Kämtz, L. S.
Nukari	60 22	24 55	1847·5	......	......	......		71 40	+07	71·8		10·51	......	10·51		Kämtz, L. S.
Helsingfors	60 10	24 57	1830·5	10 45 w.	1 06 e.	9·7 w.	9·7 w.	72 00	−18	71·7	71·5	10·60	......	10·60	10·54	Hansteen.
			1833·0	......	......	......		71 40	−14	71·4		......	......	......		Halleström.
			1840·0	......	......	......		71 25	−04	71·4		......	......	......		Nervander.
			1847·5	......	......	......		71 22	+07	71·5		10·47	......	10·47		Kämtz, L. S.
			1849·0	......	......	......		71 20	+10	71·5		......	......	......		Kämtz, L. S.
Borga	60 24	25 36	1830·5	......	......	......		71 34	−18	71·3		10·67	......	10·67		Hansteen.
Tuomala	64 25	26 00	1847·5	......	......	......		73 31	+05	73·6		10·83	......	10·83		Kämtz, L. S.
Aho	64 02	26 27	1847·5	......	......	......		73 25	+05	73·5		10·67	......	10·67		Kämtz, L. S.
Abborfors	60 30	26 30	1847·5	......	......	......		71 20	+05	71·4		10·52	......	10·52		Kämtz, L. S.

ZONE V.—Lat. 60° to 65° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.		Inclination. Observed.	Inclination. Corr. to Epoch 1842·5.	Inclination. Corrected.		Force in British units. Observed.	Force. Corr. to Epoch 1842·5.	Force. Corrected.		Observers.
	° ′	° ′		° ′	° ′	°		° ′	°	°						
[illegible]	63 17	27 00	1847·5	......	......	......		73 11	-·05	73·1		10·60	......	10·60		Kämtz, L. S.
[illegible]	63 37	27 03	1847·5	......	......	......		73 0[illegible]	-·05	73·2		10·63	......	10·63		Kämtz, L. S.
[illegible]	63 55	27 11	1830·5	9 15 w.	1 05 e.	8·2 w.		71 42	-·12	71·5		10·69	......	10·69		Hansteen.
[illegible]	63 22	27 13	1847·5	......	......	......		72 53	+·05	73·0		11·30	......	11·30		Kämtz, L. S.
[illegible]	60 33	27 30	1830·5	8 02 w.	1 06 e.	6·9 w.	6·9 w.	71 50	-·12	71·6	71·6	10·68	......	10·68	10·55	Hansteen.
			1847·5	......	......	......		71 32	+·05	71·6		10·43	......	10·43		Kämtz, L. S.
Kuopio	62 55	27 53	1847·5	......	......	......		72 51	+·05	73·0		10·59	......	10·59		Kämtz, L. S.
Warkaus Sluss	62 20	27 58	1842·5	......	......	......		72 32	......	72·5		......	......	......		Kämtz, L. S.
[illegible]	60 05	28 07	1830·5	......	......	......		70 50	-·12	70·6		......	......	......		[illegible]
[illegible]	61 32	28 15	1847·5	......	......	......		72 03	+·05	72·2		10·52	......	10·52		Kämtz, L. S.
[illegible]	61 04	28 16	1847·5	......	......	......		71 52	+·05	72·0		10·55	......	10·55		Kämtz, L. S.
Wiborg	60 41	28 50	1830·5	7 12 w.	1 06 e.	6·1 w.	6·1 w.	71 42	-·12	71·5	71·3	10·67	......	10·67	10·67	Hansteen.
			1847·0	......	......	......		70 58	+·05	71·1		......	......	......		Kämtz, L. S.
Imatra Falls	61 11	28 55	1847·0	......	......	......		71 51	+·05	71·9		10·55	......	10·55		Kämtz, L. S.
[illegible]	60 44	33 33	1870·5	1 23 e.	2 48 w.	1·4 w.		71 49	+·11	72·1		10·95	......	10·95		Belavenetz.
[illegible]	60 55	34 55	1849·0	......	......	......		71 34	+·01	71·6		10·67	......	10·67		Kämtz, L. S.
[illegible]	61 57	34 59	1831·0	2 50 w.	1 09 e.	1·7 w.		......	......	......		......	......	......		Reinecke.
[illegible]	61 46	35 28	1830·0	2 45 w.	1 15 e.	1·5 w.		......	......	......		......	......	......		[illegible]
Wytegra	61 00	36 27	1841·5	......	......	......	0·6 w.	71 31	......	71·5	71·6	11·30	......	11·30	10·99	Sawelief.
			1849·0	......	......	......		71 51	-·03	71·8		10·82	......	10·82		Kämtz, L. S.
			1870·5	2 15 [illegible]	2 48 w.	0·6 w.		71 34	+·14	71·8		10·85	......	10·85		Belavenetz.
[illegible]	64 55	36 30	1830·0	1 00 e.	1 15 [illegible]	0·3 [illegible]		......	......	......		......	......	......		Reinecke.
[illegible]	60 48	37 30	1849·0	......	......	......		71 25	+·03	71·5		10·78	......	10·78		Kämtz, L. S.
[illegible]	64 00	37 55	1829·0	1 00 w.	1 21 e.	0·4 [illegible]		......	......	......		......	......	......		Reinecke.
Onega	63 51	38 09	1829·5	1 05 w.	1 18 e.	0·2 [illegible]		73 38	-·03	73·5		......	......	......		Reinecke.
[illegible]	64 48	38 30	1832·0	0 40 w.	1 00 e.	0·3 [illegible]		......	......	......		......	......	......		[illegible]
Kargopol	61 43	38 57	1849·0	......	......	......		72 06	+·03	72·2		10·84	......	10·84		Kämtz, L. S.
[illegible]	61 55	39 12	1849·0	......	......	......		72 15	+·05	72·3		10·86	......	10·86		Kämtz, L. S.
[illegible]	64 35	39 54	1832·0	1 40 [illegible]	1 00 e.	2·7 [illegible]		......	......	......		......	......	......		Reinecke.
[illegible]	62 10	40 10	1849·0	......	......	......		72 33	+·03	72·6		10·85	......	10·85		Kämtz, L. S.
Mouth of the Dwina	64 55	40 17	1829·0	2 01 [illegible]	1 06 e.	3·1 [illegible]	2·8	......	......	......		......	......	......		Reinecke.
			1838·0	4 01 [illegible]	1 33 w.	2·5 [illegible]		......	......	......		......	......	......		[illegible]
Fort Novodwinsk	64 42	40 28	1832·5	1 45 [illegible]	1 00 e.	2·8 [illegible]		......	......	......		......	......	......		Reinecke.
Lapominka	64 47	40 30	1832·5	2 00 [illegible]	1 00 e.	3·0 [illegible]		......	......	......		......	......	......		Reinecke.
Archangel	64 34	40 33	1832·0	2 19 [illegible]	1 03 e.	3·5 [illegible]	3·2 e.	74 09	−·05	74·1	74·1	11·06	......	11·06	11·05	Reinecke.
			1849·0	......	......	......		73 59	+·03	74·0		10·97	......	10·97		Kämtz, L. S.
			1870·5	5 15 e.	2 48 w.	3·0 [illegible]		73 51	+·11	74·1		11·13	......	11·13		Belavenetz.
Pleskaia	62 35	40 55	1849·0	......	......	......		72 47	+·02	72·8		10·85	......	10·85		Kämtz, L. S.
Bobrowsk	64 28	41 00	1849·0	......	......	......		74 01	+·02	74·1		10·99	......	10·99		Kämtz, L. S.
Kaduish	62 55	41 30	1849·0	......	......	......		73 20	+·02	73·4		10·96	......	10·96		Kämtz, L. S.
Cholmagory	64 12	41 50	1841·0	......	......	......		73 28	+·01	73·5		......	......	......		Sawelief.
Pianda	62 56	42 35	1870·5	4 57 e.	2 48 w.	2·2 e.		72 59	+·07	73·1		10·93	......	10·93		Belavenetz.
Veliky	60 16	46 18	1870·5	7 09 e.	2 48 w.	4·4 e.		71 47	+·07	71·9		11·17	......	11·17		Belavenetz.
Beresow	63 56	65 04	1829·0	11 46 e.	2 12 w.	9·6 e.		71 54	−·04	71·9		12·05	+·01	12·06		Erman.
Kunduwansk	63 17	65 06	1829·0	......	......	......		71 03	−·03	71·0		12·09	+·01	12·10		Erman.
Schorkal	62 44	65 34	1829·0	11 12 e.	2 08 w.	9·1 e.		......	......	......		......	......	......		Erman.
Koadinsk	62 24	66 28	1829·0	......	......	......		73 42	−·02	73·7		12·19	+·01	12·20		Erman.
Kewaschinsk	61 37	67 45	1829·0	......	......	......		73 26	−·01	73·4		12·10	+·01	12·11		Erman.
Jelisarowo	61 15	68 21	1829·0	11 39 e.	2 06 w.	9·6 e.		......	......	......		......	......	......		Erman.
Samarowo	60 45	68 42	1829·0	......	......	......		73 07	−·01	73·1		12·10	+·01	12·11		Erman.
Sawodinsk	60 13	69 34	1829·0	......	......	......		72 45	+·01	72·8		12·03	+·01	12·04		Erman.
Kangatowo	63 27	87 22	1829·5	13 14 e.	2 23 w.	10·9 e.		76 15	+·11	76·4		12·63	+·03	12·66		Hansteen.
Fatianskoie	64 04	87 37	1829·5	13 47 e.	2 26 w.	11·4 e.		76 38	+·11	76·8		12·76	+·04	12·80		Hansteen.
Werchne Inbak	63 10	87 38	1835·5	13 14 e.	1 17 w.	12·0 e.		75 58	+ ·7	76·1		......	......	......		Federow.
Tschernoostrowa	64 37	87 38	1829·5	14 38 e.	2 27 w.	12·2 e.		76 56	+·11	77·1		12·71	+·04	12·75		Hansteen.
Baikinskoie	64 59	87 54	1829·5	14 38 e.	2 30 w.	12·1 e.		77 20	+·11	77·5		12·82	+·04	12·86		Hansteen.
Tschulkowo	62 46	88 23	1829·5	12 36 e.	2 16 w.	10·3 e.		75 42	+·12	75·9		12·72	+·04	12·76		Hansteen.
Lebedowo	62 08	89 09	1829·5	10 39 e.	2 15 w.	8·4 e.		75 29	+·12	75·7		12·86	+·04	12·90		Hansteen.
Dubtscheskoie	61 02	89 37	1829·5	9 51 e.	2 08 w.	7·7 e.		74 39	+·12	74·9		12·63	+·04	12·67		Hansteen.
Komsino	61 52	89 42	1829·5	......	......	......		75 19	+·13	75·5		12·73	+·04	12·77		Hansteen.
Somorokowo	61 40	89 48	1829·5	10 16 e.	2 12 w.	8·1 e.		75 20	+·13	75·6		12·89	+·04	12·93		Hansteen.
Osinowi	61 20	89 50	1829·5	......	......	......		75 16	+·13	75·5		12·76	+·04	12·80		Hansteen.
Mikulina	60 26	90 05	1829·5	......	......	......		74 28	+·14	74·7		12·73	+·04	12·77		Hansteen.
Mouth of the Sym	60 17	90 21	1835·5	10 34 e.	1 17 w.	9·3 e.		74 43	+ ·7	74·8		......	......	......		Federow.

ZONE V.—Lat. 60° to 65° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.	Inclination. Observed.	Inclination. Cor. to Epoch 1842·5.	Inclination. Corrected.	Force in British units. Observed.	Force in British units. Cor. to Epoch 1842·5	Force in British units. Corrected.	Observers.
	° ′	° ′		° ′	° ′	°	° ′	′	°				
Serebrinikowa	60 02	90 34	1829·5	9 40 E.	2 02 W.	7·6 E.	74 19	+14	74·6	12·71	+·04	12·75	Hansteen.
Kantinsk	60 25	114 17	1829·5	1 35 W.	1 20 E.	0·3 W. } 0·3 W.	74 37	+30	75·1 } 75·0	13·10	+·07	13·17 } 13·23	Due.
			1829·5	......	......	......	74 32	+30	75·0	13·23	+·07	13·30	Erman.
Jerbinsk	60 28	116 15	1829·5	1 48 W.	1 18 E.	0·5 W.	74 17	+30	74·8	13·01	+·07	13·08	Erman.
Nelensk	60 00	118 28	1829·5	1 47 W.	1 10 E.	0·6 W.	......	......	......	......	......	......	Erman.
Olekma	60 22	119 33	1829·5	2 25 W.	1 06 E.	1·3 W. } 1·3 W.	74 09	+32	74·7 } 74·8	13·02	+·08	13·10 } 13·06	Erman.
			1829·5	2 16 W.	1 06 E.	1·2 W.	74 25	+32	75·0	12·94	+·08	13·02	Due.
Wiluisk	63 45	122 02	1829·5	2 11 W.	1 15 E.	0·9 W.	76 53	+30	77·4	13·54	+·08	13·62	Due.
Bogadiach	63 51	123 13	1829·5	1 34 W.	1 12 E.	0·4 W.	76 38	+31	77·2	13·36	+·09	13·45	Due.
Marchipskaia	60 36	123 29	1829·5	2 19 W.	1 00 E.	1·3 W.	74 00	+33	74·6	12·93	+·09	13·02	Due.
Sanajachtask	60 53	123 34	1829·5	......	......	......	73 41	+33	74·2	13·06	+·09	13·15	Erman.
Tschemetskaia	63 50	124 22	1829·5	2 19 W.	1 07 E.	1·2 W.	76 16	+31	76·8	13·10	+·10	13·20	Due.
Negodiach	63 41	125 42	1829·5	2 23 W.	1 05 E.	1·3 W.	76 01	+32	76·6	13·05	+·10	13·15	Due.
Issik	60 47	125 58	1829·5	2 51 W.	0 54 E.	2·0 W.	......	......	......	......	......	......	Erman.
Schurinskaia	60 57	126 07	1829·5	3 21 W.	0 56 E.	2·4 W.	74 04	+34	74·6	13·05	+·10	13·15	Due.
Titariskaia	61 40	126 48	1829·5	......	......	......	74 10	+34	74·7	13·08	+·19	13·17	Due.
Tojou Aruin	61 40	127 46	1829·5	......	......	......	73 54	+34	74·5	12·90	+·10	13·00	Erman.
Katingari	62 48	128 58	1829·5	5 48 W.	0 54 E.	4·9 W.	75 06	+34	75·7	13·04	+·11	13·15	Due.
Yakuzk	62 01	129 45	1820·5	5 05 W.	......	...... } 5·0 W.	73 51	+57	74·8 } 74·9	......	......	...... } 13·15	Wrangel.
			1829·5	5 58 W.	0 51 E.	5·1 W.	74 24	+34	75·0	13·04	+·10	13·14	Due.
			1829·5	5 52 W.	0 51 E.	5·0 W.	74 18	+34	74·9	13·06	+·10	13·16	Erman.
R. Aldan	63 18	130 51	1821·5	......	......	......	75 10	+55	76·1	......	......	......	Wrangel.
[illegible]	[illegible] 01	131 50	1829·5	4 40 W.	0 47 E.	3·9 W.	74 00	+35	74·6	13·13	+·11	13·24	Erman.
[illegible]	[illegible] 53	131 54	1829·5	4 37 W.	0 43 E.	3·9 W.	......	......	......	......	......	......	Kosmin.
Bulboklunta	64 06	132 31	1821·5	......	......	......	75 49	+55	76·7	......	......	......	Wrangel.
Lebegino	62 11	133 42	1829·5	2 13 W.	0 43 E.	1·5 W.	73 56	+37	74·6	12·95	+·12	13·07	Erman.
Nochinsk	61 57	134 57	1829·5	2 18 W.	0 40 E.	1·6 W.	73 37	+36	74·2	13·04	+·12	13·16	Erman.
Aldanski Perewos	61 53	135 34	1829·5	3 09 W.	0 39 E.	2·5 W.	73 21	+36	74·0	12·82	+·12	12·94	Erman.
Tschernolies	61 31	136 23	1829·5	3 37 W.	0 36 E.	3·0 W.	73 08	+37	73·8	12·92	+·12	13·04	Erman.
Garnastach	61 30	137 00	1829·5	3 50 W.	0 35 E.	3·3 W.	73 12	+37	73·8	12·90	+·13	13·03	Erman.
Allachuna	61 09	138 10	1829·5	......	......	......	72 35	+38	73·2	12·68	+·12	12·80	Erman.
Antscha	61 01	138 39	1829·5	2 41 W.	0 31 E.	2·2 W.	......	......	......	......	......	......	Erman.
[illegible]	60 54	140 35	1829·5	......	......	......	72 10	+37	72·8	12·87	+·13	13·00	Erman.
[illegible]	60 40	141 17	1829·5	2 34 W.	0 25 E.	2·2 W.	......	......	......	......	......	......	Erman.
Arki	60 06	142 20	1829·5	......	......	......	71 18	+38	71·9	12·47	+·13	12·60	Erman.
At sea	60 13	176 43	1848·5	......	......	......	71 35	......	71·6	......	......	......	Moore.
At sea	60 50	176 49	1850·5	15 47 E.	......	15·8 E.	......	......	......	......	......	......	Kellett.
At sea	61 20	177 23	1850·5	14 07 E.	......	14·1 E.	......	......	......	......	......	......	Collinson.
At sea	61 21	177 42	1850·5	......	......	......	72 20	......	72·3	......	......	......	Collinson.
At sea	60 52	178 46	1848·5	......	......	......	70 54	......	70·9	......	......	......	Moore.
At sea	61 28	178 47	1848·5	......	......	......	72 51	......	72·8	......	......	......	Moore.
At sea	61 40	180 18	1851·5	......	......	......	71 56	......	71·9	......	......	......	Collinson.
At sea	60 27	180 28	1848·5	......	......	......	71 52	......	71·9	......	......	......	Moore.
At sea	62 20	180 50	1850·5	18 55 E.	......	18·9 E.	......	......	......	......	......	......	Kellett.
At sea	61 32	180 54	1851·5	......	......	......	70 52	......	70·9	......	......	......	Collinson.
On ice	62 05	181 10	1850·5	......	......	......	72 58	......	73·0	......	......	......	Collinson.
At sea	62 12	181 20	1850·5	18 28 E.	......	18·5 E.	......	......	......	......	......	......	Kellett.
Thaddai	62 36	181 31	1828·5	17 37 E.	......	17·6 E.	......	......	......	......	......	......	Lütke.
At sea	62 27	181 44	1850·5	19 54 E.	......	19·9 E.	......	......	......	......	......	......	Collinson.
At sea	60 35	181 41	1848·5	......	......	......	72 22	......	72·4	......	......	......	Moore.
At sea	62 35	182 10	1850·5	18 44 E.	......	18·7 E.	......	......	......	......	......	......	Kellett.
At sea	61 18	182 23	1848·5	......	......	......	73 07	......	73·1	......	......	......	Moore.
At sea	60 11	183 03	1849·5	20 43 E.	......	20·7 E.	......	......	......	......	......	......	Kellett.
At sea	62 27	183 22	1848·5	......	......	......	74 11	......	74·2	......	......	......	Moore.
At sea	64 32	183 38	1851·5	......	......	......	75 40	......	75·7	......	......	......	Collinson.
At sea	64 26	184 34	1850·5	18 17 E.	......	18·3 E.	......	......	......	......	......	......	Collinson.
At sea	62 35	184 43	1849·5	19 21 E.	......	19·4 E.	......	......	......	......	......	......	Kellett.
At sea	63 08	184 56	1848·5	......	......	......	74 36	......	74·6	......	......	......	Moore.
At sea	63 20	184 59	1850·5	21 59 E.	......	22·0 E.	......	......	......	......	......	......	Collinson.
At sea	63 22	185 10	1850·5	21 47 E.	......	21·8 E.	......	......	......	......	......	......	Kellett.
At sea	64 16	186 26	1828·5	20 17 E.	......	20·3 E.	......	......	......	......	......	......	Lütke.
At sea	64 02	186 30	1850·5	20 39 E.	......	20·7 E.	......	......	......	......	......	......	Collinson.
Port Providence	64 26	186 53	1849·0	......	......	......	75 10	......	75·2	......	......	......	Moore.
At sea	63 45	187 01	1849·5	22 22 E.	......	22·4 E.	......	......	......	......	......	......	Kellett.

ZONE V.—Lat. 60° to 65° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination.				Inclination.				Force in British units.				Observers.
				[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		
	° ′	° ′		° ′		°		° ′		°						
At sea	63 29	187 28	1848·5	......	......	......		75 08	......	75·1		......	......	......		Moore.
At sea	60 15	187 30	1827·5	19 37 E.	......	19·6 E.		......	......	......		......	......	......		Lütke.
Ongayak	64 24	187 40	1849·0	......	......	......		75 25	......	75·4		......	......	......		Moore.
At sea	62 47	187 44	1848·5	......	......	......		75 25	......	75·4		......	......	......		Moore.
At sea	63 33	187 46	1854·5	22 15 E.	......	22·3 E.		......	......	......		......	......	......		Collinson.
At sea	64 12	188 05	1850·5	22 52 E.	......	22·9 E.		......	......	......		......	......	......		Kellett.
At sea	63 48	188 15	1850·5	......	......	......		75 04	......	75·1		......	......	......		Collinson.
At sea	62 16	188 38	1852·5	21 06 E.	......	21·1 E.		......	......	......		......	......	......		Crane.
At sea	64 12	188 38	1849·5	22 56 E.	......	22·9 E.		......	......	......		......	......	......		Kellett.
At sea	64 12	188 52	1854·5	23 26 E.	......	23·4 E.		......	......	......		......	......	......		Collinson.
At sea	62 40	189 18	1852·5	22 17 E.	......	22·3 E.		......	......	......		......	......	......		Crane.
At sea	63 11	189 22	1848·5	......	......	......		73 25	......	73·4		......	......	......		Moore.
At sea	61 44	189 38	1852·5	22 18 E.	......	22·3 E.		......	......	......		......	......	......		Crane.
At sea	64 47	189 47	1849·5	24 58 E.	......	25·0 E.		......	......	......		......	......	......		Kellett.
At sea	61 01	190 06	1852·5	20 43 E.	......	20·7 E.		......	......	......		......	......	......		Crane.
At sea	60 38	190 44	1852·5	20 54 E.	......	20·9 E.		......	......	......		......	......	......		Crane.
At sea	63 14	191 31	1850·5	23 06 E.	......	23·1 E.		......	......	......		......	......	......		Kellett.
At sea	60 38	191 46	1850·5	......	......	......		73 12	......	73·2		......	......	......		Collinson.
At sea	63 01	192 39	1852·5	22 23 E.	......	22·4 E.		......	......	......		......	......	......		Crane.
At sea	60 24	192 40	1850·0	21 56 E.	......	21·9 E.		......	......	......		......	......	......		Collinson.
At sea	64 35	192 57	1850·5	27 09 E.	......	27·1 E.		......	......	......		......	......	......		Kellett.
At sea	64 34	193 25	1850·0	26 22 E.	......	26·4 E.		......	......	......		......	......	......		Collinson.
At anchor	62 27	193 36	1850·5	......	......	......		74 44	......	74·7		......	......	......		Collinson.
At sea	63 53	194 00	1850·5	24 30 E.	......	24·5 E.		......	......	......		......	......	......		Kellett.
At sea	63 30	194 21	1852·5	25 11 E.	......	25·2 E.		......	......	......		......	......	......		Crane.
At sea	61 02	194 24	1852·5	25 28 E.	......	25·5 E.		......	......	......		......	......	......		Crane.
At sea	64 15	195 08	1850·5	25 32 E.	......	25·5 E.		......	......	......		......	......	......		Kellett.
At sea	64 23	195 39	1851·0	26 27 E.	......	26·5 E.		......	......	......		......	......	......		Collinson.
At sea	63 53	195 55	1850·5	29 00 E.	......	29·0 E.		......	......	......		......	......	......		Kellett.
At sea	63 49	196 30	1850·5	29 00 E.	......	29·0 E.		......	......	......		......	......	......		Kellett.
At sea	61 04	197 47	1851·0	28 07 E.	......	28·1 E.		......	......	......		......	......	......		Collinson.
Norton Sound	63 28	198 18	1827·5	30 30 E.	......	30·5 E.		......	......	......		......	......	......		Lütke.
Port Etches	60 21	213 19	1837·5	31 39 E.	......	31·7 E.		76 03	......	76·1		12·94	......	12·94		Belcher.
Fort Norman	64 31	235 16	1844·5	45 12 E.	......	45·2 E.		82 34	......	82·6		13·63	......	13·63		Lefroy.
Fort Simpson	61 51	238 35	1825·5	37 42 E.	?	......	° 37·8 E.	81 54	?	......	° 81·9	......	......	?	13·84	Franklin.
			1837·5	37 10 E.	?	......		......	?	......		......	......	?		Simpson.
			1844·5	37 48 E.	......	37·8 E.		81 52	......	81·9		13·84	......	13·84		Lefroy.
Little Lake	61 23	242 15	1844·5	37 06 E.	......	37·1 E.		......	......	......		......	......	......		Lefroy.
Big Island	61 12	243 22	1844·5	35 28 E.	......	35·5 E.		82 09	......	82·2		......	......	......		Lefroy.
Hay River	60 48	244 42	1844·5	35 36 E.	......	35·6 E.		......	......	......		......	......	......		Lefroy.
Fort Resolution	61 10	246 15	1833·5	37 20 E.	......	37·3 E.	37·2 E.	82 03	......	82·1	82·5	......	......	......	13·99	Back.
			1837·5	37 16 E.	......	37·3 E.		......	......	......		......	......	......		Simpson.
			1844·5	37 07 E.	......	37·1 E.		82 45	......	82·8		13·99	......	13·99		Lefroy.
Portage Grand Detour	60 22	247 00	1844·5	35 53 E.	......	35·9 E.		82 34	......	82·6		......	......	......		Lefroy.
Fort Reliance	62 46	250 59	1834·5	35 19 E.	......	35·3 E.		84 01	......	84·0		......	......	......		Back.
Musk-ox Rapid	64 33	255 20	1834·5	44 24 E.	......	44·4 E.		85 54	......	85·9		......	......	......		Back.
At sea	60 50	276 57	1846·5	30 35 W.	......	30·6 W.		......	......	......		......	......	......		Moore.
At sea	61 07	277 10	1846·5	......	......	......		87 00	......	87·0		13·19	......	13·19		Moore.
At sea	60 45	277 15	1846·5	......	......	......		86 41	......	86·7		13·58	......	13·58		Moore.
At sea	60 25	277 18	1846·5	......	......	......		86 36	......	86·6		13·22	......	13·22		Moore.
At sea	60 26	277 52	1846·5	34 00 W.	......	34·0 W.		85 20	......	85·3		13·57	......	13·57		Moore.
At sea	62 20	278 48	1846·5	......	......	......		86 07	......	86·1		......	......	......		Moore.
At sea	62 10	279 50	1846·5	......	......	......		87 01	......	87·0		13·36	......	13·36		Moore.
At sea	63 17	281 05	1846·5	58 15 W.	......	58·3 W.		86 35	......	86·6		13·55	......	13·55		Moore.
At sea	63 11	282 31	1846·5	59 21 W.	......	59·4 W.		......	......	......		......	......	......		Moore.
At sea	63 13	282 55	1846·5	55 28 W.	......	55·5 W.		86 25	......	86·4		13·40	......	13·40		Moore.
At sea	62 56	283 05	1846·5	52 16 W.	......	52·3 W.		86 24	......	86·4		13·16	......	13·16		Moore.
At sea	63 10	283 10	1846·5	......	......	......		86 19	......	86·3		13·33	......	13·33		Moore.
On ice	63 15	284 41	1846·5	58 54 W.	......	58·9 W.		85 45	......	85·8		13·60	......	13·60		Moore.
At sea	63 20	284 53	1846·5	......	......	......		85 34	......	85·6		13·32	......	13·32		Moore.
On ice	63 14	284 58	1846·5	58 54 W.	......	58·9 W.		85 45	......	85·7		13·60	......	13·60		Moore.
At sea	63 12	286 01	1846·5	59 51 W.	......	59·9 W.		85 02	......	85·0		13·44	......	13·44		Moore.

ZONE V.—Lat. 60° to 65° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.	Declination. Mean	Inclination. Observed.	Inclination. Cor. to Epoch 1842·5.	Inclination. Corrected.	Inclination. Mean	Force in British units. Observed.	Force. Cor. to Epoch 1842·5.	Force. Corrected.	Force. Mean	Observers.
At sea	62 57	287 19	1846·5	58 36 w.	......	58·9 w.		84 52	......	84·9		13·25	......	13·25		Moore.
At sea	62 47	288 27	1846·5	58 20 w.	......	58·3 w.		84 50	......	84·8		13·26	......	13·26		Moore.
At sea	62 01	289 00	1846·5	......	......	......		85 42	......	85·7		13·12	......	13·12		Moore.
At sea	62 16	289 00	1846·5	......	......	......		84 50	......	84·8		13·25	......	13·25		Moore.
At sea	61 51	289 40	1846·5	51 49 w.	......	51·8 w.		85 01	......	85·0		13·10	......	13·10		Moore.
At sea	62 35	290 02	1846·5	......	......	......		84 46	......	84·8		13·21	......	13·21		Moore.
Savage Island	62 31	290 03	1821·5	52 35 w.	?	?		84 46	......	84·8		......	......	......		Parry and Fisher.
At sea	62 24	290 29	1846·5	58 28 w.	......	58·5 w.		......	......	......		......	......	......		Moore.
At sea	62 13	290 47	1846·5	59 20 w.	......	59·3 w.		......	......	......		......	......	......		Moore.
At sea	61 51	290 55	1846·5		......	......		85 01	......	85·0		......	......	......		Moore.
At sea	62 01	291 05	1846·5	60 22 w.	......	60·4 w.		......	......	......		......	......	......		Moore.
At sea	61 55	291 21	1846·5	......	......	......		83 32	......	83·5		13·41	......	13·41		Moore.
At sea	62 27	292 23	1846·5	......	......	......		......	......	......		12·38	......	12·38		Moore.
At sea	61 55	292 29	1846·5	......	......	......		84 32	......	84·5		13·41	......	13·41		Moore.
At sea	62 21	292 51	1846·5	......	......	......		83 55	......	83·9		12·25	......	12·26		Moore.
At sea	61 28	293 13	1846·5	......	......	......		83 32	......	83·5		13·41	......	13·41		Moore.
On ice	61 36	293 19	1821·5	51 42 w.	......	51·7 w.		......	......	......		......	......	......		Parry and Fisher.
At sea	61 14	294 12	1846·5	56 52 w.	......	56·9 w.		83 54	......	83·9		12·91	......	12·91		Moore.
On ice	61 10	294 39	1821·5	52 54 w.	......	52·9 w.		......	......	......		......	......	......		Parry and Fisher.
At sea	61 00	295 00	1846·5	55 56 w.	......	55·9 w.		83 15	......	83·3		13·20	......	13·20		Moore.
On ice	61 13	295 17	1821·5	52 42 w.	......	52·7 w.		84 00	......	84·0		......	......	......		Parry and Fisher.
At sea	61 19	295 36	1821·5	52 45 w.	......	52·8 w.		......	......	......		......	......	......		Parry and Fisher.
At sea	61 31	295 46	1846·5	58 33 w.	......	58·6 w.		84 02	......	84·0		13·29	......	13·20		Moore.
At sea	62 25	296 23	1846·5	......	......	......		83 55	......	83·9		12·38	......	12·38		Moore.
At sea	60 10	296 35	1846·5	56 22 w.	......	56·4 w.		83 51	......	83·8		12·20	......	12·20		Moore.
On ice	63 26	297 32	1819·5	61 23 w.	......	61·4 w.		......	......	......		......	......	......		Parry and Sabine.
On ice	62 44	298 01	1819·5	60 29 w.	......	60·5 w.		......	......	......		......	......	......		Parry and Sabine.
On ice	61 00	298 10	1819·5	61 12 w.	......	61·2 w.		83 05	......	83·1		12·11	......	12·11		Parry and Sabine.
At sea	61 02	298 29	1846·5	57 33 w.	......	57·6 w.		82 39	......	82·7		......	......	......		Moore.
At sea	61 50	298 20	1846·5	58 56 w.	......	58·9 w.		82 14	......	82·2		12·96	......	12·96		Moore.
At sea	61 10	298 25	1846·5	......	......	......		82 16	......	82·3		12·87	......	12·87		Moore.
At sea	61 11	298 40	1846·5	55 16 w.	......	55·3 w.		......	......	......		......	......	......		Moore.
At sea	60 58	299 10	1846·5	55 40 w.	......	55·7 w.		82 10	......	82·2		12·96	......	12·96		Moore.
At sea	60 56	299 48	1846·5	......	......	......		82 00	......	82·0		......	......	......		Moore.
[illegible]	61 16	308 12	1860·5	62 02 w.	......	62·0 w.		80 35	......	80·6		......	......	......		McClintock.
Fiskernæs	63 05	309 26	1853·5	......	......	......		80 41	......	80·7	80·6	......	......	......		Kane.
			1857·5	......	......	......		80 29	......	80·5		......	......	......		McClintock.
Frederikshaab	62 05	310 00	1860·5	57 13 w.	......	57·2 w.		......	......	......		......	......	......		Davis.
Julianehaab	60 43	313 59	1861·0	54 27 w.	......	54·5 w.		79 06	......	79·1		......	......	......		McClintock.
Frederiksdal	60 00	315 11	1829·5	50 30 w.	......	50·5 w.		......	......	......		......	......	......		Graah.
Christian's Channel	60 10	317 00	1829·5	50 50 w.	......	50·8 w.		......	......	......		......	......	......		Graah.
Ravnen Island	61 46	317 32	1829·5	52 20 w.	......	52·3 w.		......	......	......		......	......	......		Graah.
Griffenfeldt	63 00	318 10	1829·5	53 30 w.	......	53·5 w.		......	......	......		......	......	......		Graah.
Reikiavik	64 08	338 05	1836·5	43 14 w.	......	43·2 w.	44·2 w.	76 57	......	77·0	76·7	......	......	......	11·82	Lottin.
			1839·5	......	......	......		76 44	......	76·7		11·82	......	11·82		Gaimard.
			1860·5	45 07 w.	......	45·1 w.		......	......	......		......	......	......		Davis.
			1860·5	44 08 w.	......	44·1 w.		76 23	......	76·4		......	......	......		McClintock.
Thingvellir	64 15	338 50	1836·5	40 08 w.	......	40·1 w.		76 04	......	76·1		......	......	......		Lottin.
Selsund	63 54	340 12	1836·5	40 49 w.	......	40·8 w.		76 41	......	76·7		......	......	......		Lottin.
Thorshavn	62 01	353 15	1831·5	30 50 w.	......	30·8 w.	29·7 w.	......	......	......		......	......	......		Vidal.
			1860·5	29 37 w.	......	29·6 w.		......	......	......		......	......	......		Davis.
			1868·5	28 32 w.	......	28·5 w.		......	......	......		......	......	......		May.
Lerwick	60 09	358 53	1818·5	......	......	......	26·8 w.	74 22	−48	73·6	73·6	10·71	+·03	10·74	10·70	Sabine.
			1838·5	27 07 w.	0 22 E.	26·8 w.		73 45	− 8	73·6		10·65	......	10·65		Ross.
			1858·5	25 18 w.	1 30 w.	26·8 w.		73 13	+32	73·7		10·72	......	10·72		Welsh.
Balta Island	60 45	359 14	1831·0	28 38 w.	1 04 E.	27·6 w.		......	......	......		......	......	......		Vidal.

ZONE VI.—LATITUDE 65° TO 70° N.

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ZONE VI.—Lat. 65° to 70° N.

[illegible]	[illegible]	[illegible]	[illegible]	Declination.				Inclination.				Force in British units.				Observers.
				[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]d.	Cor. to Epoch 1842·5.	Corrected.		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]		[illegible]	......	11·44		Keilhau.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]		[illegible]	......	10·69		Keilhau.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]		[illegible]	......	10·96		Keilhau.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]		[illegible]	......	11·23		Keilhau.
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]			[illegible]	[illegible]	[illegible]		[illegible]	......	11·10		Keilhau.
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]			[illegible]	[illegible]	[illegible]		[illegible]	......	11·06		Keilhau.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]		[illegible]	......	......		Keilhau.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]		[illegible]	......	11·26		Keilhau.
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]			[illegible]	[illegible]	[illegible]		[illegible]	......	11·60		Keilhau.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]		[illegible]	......	11·40		Keilhau.
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]			[illegible]	[illegible]	[illegible]		[illegible]	......	11·00		Keilhau.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	......	11·55	11·12	Keilhau.
			[illegible]			[illegible]		[illegible]	11	[illegible]		[illegible]	......	10·93		Kämtz, L. S.
			[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	......	10·87		Lœnström.
			[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	......	11·14		Belavenetz.
Kirlli-jarvi	69 05	20 40	1849·5	......	......	......		75 52	+11	76·1		10·90	......	10·90		Kämtz, L. S.
Pitea	65 19	21 30	1825·5	......	......	......		74 09	−25	73·7		11·24	......	11·24		Hansteen.
Kaaresuando	68 24	22 08	1840·0	10 52 w.	0 15 E.	10·6 w.		75 47	−03	75·7	75·8	11·18	......	11·18	11·00	Gaimard.
			1819·5	......	......	......		75 37	+11	75·8		10·83	......	10·83		Kämtz, L. S.
Palajoensū	68 18	22 45	1819·5	......	......	......		76 06	+11	76·3		10·92	......	10·92		Kämtz, L. S.
[illegible]	65 48	23 09	1825·5	......	......	......		74 58	−25	74·6		11·22	......	11·22		Hansteen.
[illegible]	68 07	23 22	1849·5	......	......	......		75 32	+11	75·7		10·79	......	10·79		Kämtz, L. S.
[illegible]	69 01	23 22	1810·5	12 52 w.	0 12 E.	12·7 w.		75 44	−03	75·7		11·18	......	11·18		Gaimard.
Bossekop	69 58	23 30	1840·5	10 42 w.	0 12 E.	10·5 w.		76 17	−03	76·2		11·14	......	11·14		Gaimard.
Torneo	65 52	23 30	1817·5	......	......	......		74 52	+07	75·0	75·0	11·91	......	11·91	11·42	Kämtz, L. S.
			1819·5	......	......	......		74 48	+11	75·0		10·93	......	10·93		Kämtz, L. S.
Kiexisvara	67 14	23 38	1810 0	8 19 w.	0 15 E.	8·1 w.		76 03	−03	76·0	75·9	11·52	......	11·52	11·33	Gaimard.
			1817·5	......	......	......		75 45	+07	75·9		11·15	......	11·15		Kämtz, L. S.
Haaparanda	65 51	23 40	1825·5	......	......	......	11·8 w.	75 13	−25	74·8	74·8	11·21	......	11·21	10·98	Hansteen.
			1840·0	12 07 w.	0 15 E.	11·9 w.		74 53	−03	74·8		11·10	......	11·10		Gaimard.
			1816·5	11 12 w.	0 24 w.	11·6 w.		74 35	+06	74·7		10·93	......	10·93		Loljehoer.
			1849·5	......	......	......		74 28	+11	74·7		10·69	......	10·69		Kämtz, L. S.
Kardis	67 00	23 40	1817·5	......	......	......		75 04	+07	75·2		10·88	......	10·88		Kämtz, L. S.
Turtola	66 42	23 40	1817·5	......	......	......		74 48	+07	74·9		10·90	......	10·90		Kämtz, L. S.
Muonionisca	68 [illegible]	23 42	1840·0	......	......	......		75 46	− 3	75·7	75·7	11·20	......	11·20	11·07	Gaimard.
			1818 5	......	......	......		75 32	+10	75·7		10·95	......	10·95		Kämtz, L. S.
[illegible]	66 [illegible]	23 49	1825·5	......	......	......		75 05	−24	74·7	74·6	11·36	......	10·36	11·11	Hansteen.
			1848·5	......	......	......		74 18	+ 8	74·4		10·86	......	10·86		Kämtz, L. S.
[illegible]	66 27	23 50	1840·0	......	......	......		75 58	− 3	75·9		......	......	......		Gaimard.
[illegible]	66 35	23 52	1847·5	......	......	......		74 32	+ 7	74·7		10·87	......	10·87		Kämtz, L. S.
Kolare	67 23	23 52	1840·0	12 24 w.	0 15 E.	12·2 w.		76 07	− 4	76·1		11·34	......	11·34		Gaimard.
[illegible]	65 47	24 40	1817·5	......	......	......		74 50	+ 7	75·0		10·77	......	10·77		Kämtz, L. S.
[illegible]	65 36	25 26	1817 5	......	......	......		74 05	+ 7	74·2		10·75	......	10·75		Kämtz, L. S.
Uleaborg	65 03	25 27	1825 5	9 32 w.	1 45 E.	7·8 w.	7·8 w.	74 44	−24	74·3	74·3	10·80	......	10·80	10·78	Hansteen.
			1817·5	......	......	......		74 06	+ 7	74·2		10·75	......	10·75		Kämtz, L. S.
[illegible]	69 51	29 43	1826·5	6 30 w.	1 53 E.	4·6 w.		......	......	......		......	......	......		Reinecke.
[illegible]	69 44	30 05	1826·5	6 20 w.	1 54 E.	4·4 w.		......	......	......		......	......	......		Reinecke.
Worjima River	69 47	30 49	1826·5	5 15 w.	1 54 E.	3·4 w.		......	......	......		......	......	......		Reinecke.
Jacobs Elv	69 48	30 51	1827·5	......	......	......		76 37	−12	76·4		11·18	......	11·18		Keilhau.
Pitschinga Bay	69 42	31 21	1826·5	5 26 w.	1 54 E.	3·5 w.		......	......	......		......	......	......		Reinecke.
Waida Bay	69 57	31 58	1826·5	4 35 w.	1 56 E.	2·7 w.		......	......	......		......	......	......		Reinecke.
Volokovaia...............	69 46	32 03	1826 5	3 40 w.	1 57 E.	1·7 w.		......	......	......		......	......	......		Reinecke.
Nova Zembla Harbour	69 43	32 06	1823·5	3 30 w.	2 21 E.	1·2 w.		77 24	−12	77·2		......	......	......		Lütke.
Kandalaksh	67 08	32 26	1831·0	4 15 w.	1 26 E.	2·8 w.		75 14	− 7	75·1		......	......	......		Reinecke.
Cape Monastery	69 36	32 45	1825·5	3 45 w.	1 58 E.	1·8 w.		......	......	......		......	......	......		Reinecke.
Cape Dobriagin.........	69 28	32 52	1826 5	3 36 w.	1 58 E.	1·6 w.		......	......	......		......	......	......		Reinecke.
Kola	68 53	33 00	1832 5	2 42 w.	1 15 E.	1·5 w.	1·5 w.	......	......	......	75·9	......	......	......		Reinecke.
			1870·0	1 21 E.	2 48 w.	1·5 w.		75 40	+14	75·9		11·05	......	11·05		Belavenetz.
Cape Lavisheff	69 47	33 02	1826·5	2 50 w.	1 58 E.	6·9 w.		......	......	......		......	......	......		Reinecke.
Catherine Harbour ...	66 13	33 27	1822 5	1 35 w.	2 30 E.	0·9 E.	0·6 E.	76 24	−15	76·2	76·3	......	......	......		Lütke.
			1826·5	1 40 w.	2 03 E.	0·4 E.		76 42	−12	76·5		11·23	......	11·23		Reinecke.
			1852·5	......	......	......		76 10	−07	76·1		......	......	......		Reinecke.
Keret Village	69 17	33 33	1831·5	4 24 w.	1 25 E.	3·0 w.		......	......	......		......	......	......		Reinecke.

ZONE VI.—Lat. 65° to 70° N. (continued).

				Declination.				Inclination.				Force in British units.				Observers.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]										Reinecke.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]										Reinecke.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]						Lütke.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]										Krotoff.
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]										Reinecke.
			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		Lütke.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]						Belavenetz.
Solovetzki Monastery..	65 01	35 45	1829·5	2 15 W.	1 21 E.	0·9 W.		......	......	......		......	......	......		Reinecke.
			1860·0	0 42 E.	1 48 W.	1·1 W.	0·8 W.	......	......	......	74·0	......	......	......		Zaroubine.
			1870·5	2 26 E.	2 54 W.	0·5 W.		73 45	+14	74·0		11·06	......	11·06		Belavenetz.
Reindeer Island	69 03	36 23	1822·5	1 22 W.	2 04 E.	0·7 E.		76 29	−10	76·3		......	......	......		Lütke.
Varzouka	66 17	36 54	1831·0	0 45 W.	1 11 E.	0·4 E.		......	......	......		......	......	......		Reinecke.
Sem Ostrog	68 47	37 28	1822·5	0 30 W.	2 04 E.	1·6 E.	1·0 E.	......	......	......		......	......	......		Lütke.
			1832·0	0 45 W.	1 05 E.	0·4 E.		......	......	......		......	......	......		Reinecke.
Petrina Village	66 04	38 17	1830·5	0 30 W.	1 14 E.	0·7 E.		......	......	......		......	......	......		Reinecke.
Kitai Island	68 28	38 30	1832·0	0 10 E.	1 05 E.	1·3 E.		......	......	......		......	......	......		Reinecke.
			1849·5	......	......	......		75 51	+ 4	75·9		10·98	......	10·98		Kämtz, L. S.
Bosimiany Island	68 04	39 35	1823·5	1 17 E.	1 58 E.	2·3 E.		76 13	−10	76·1		......	......	......		Lütke.
			1832·5	1 30 E.	1 02 E.	2·5 E.	2·6 E.	76 28	−05	76·4	76·2	11·36	......	11·36	11·31	Reinecke.
			1859·5	4 34 E.	1 45 W.	2·8 E.		......	......	......		......	......	......		Zaroubine.
			1870·5	5 41 E.	2 54 W.	2·8 E.		75 54	+14	76·1		11·26	......	11·26		Belavenetz.
Swiatoi Noss	68 10	39 48	1823·5	1 00 E.	1 58 E.	3·0 E.		......	......	......		......	......	......		Reinecke.
			1830·5	......	......	2·1 E.		76 27	− 6	76·4	76·2	11·40	......	11·40		Reinecke.
			1870·5	4 08 E.	2 54 W.	2·2 E.		75 48	+14	76·0		......	......	......		Belavenetz.
Gigguinsk Island......	65 12	39 52	1832·5	0 59 W.	1 02 E.	0·2 E.		......	......	......		......	......	......		Reinecke.
Nicholsk..................	65 00	40 13	[illegible]	1 39 [illegible]	1 02 E.	2·5 E.		......	......	......		......	......	......		Reinecke.
Cape Intzo..............	65 58	40 41	1829·0	0 45 E.	1 24 E.	2·2 E.		......	......	......		......	......	......		Krotoff and Kozakoff.
Sosnovetz or Cross Island..............	66 29	40 44	1830·5	1 27 E.	1 14 E.	2·7 E.		74 58	......	75·0		......	......	......		Reinecke.
			1854·5	3 58 E.	1 14 W.	2·7 E.	2·8 E.	......	......	......	75·0	......	......	......		Ommanney.
			1855·5	4 25 E.	1 20 W.	3·1 E.		......	......	......		......	......	......		McDougall.
At sea......................	69 15	41 00	1824·5	0 57 E.	1 52 E.	2·8 E.		......	......	......		......	......	......		Lütke.
Sazonoff Bay	67 41	41 02	1828·5	0 45 E.	1 27 E.	2·2 E.		......	......	......		......	......	......		Pakhtussoff and Milukoff.
Orloff Light	67 12	41 22	1861·5	6 18 E.	1 58 W.	4·3 E.		......	......	......		......	......	......		Zaroubine.
Three Islands	67 06	41 26	1827·5	1 17 E.	1 33 E.	2·8 E.		......	......	......		......	......	......		Reinecke.
Cape Woronoff.........	66 31	42 20	1828·5	2 10 E.	1 27 E.	3·6 E.		......	......	......		......	......	......		Krotoff.
At sea.....................	68 33	42 26	1824·5	3 30 E.	1 52 E.	5·4 E.		......	......	......		......	......	......		Lütke.
Morjovetz Island	66 45	42 28	1827·5	2 20 E.	1 33 E.	3·9 E.		......	......	......		......	......	......		Tunker and Milnkoff.
Bank in White Sea ...	67 11	42 48	1827·5	2 30 E.	1 33 E.	4·1 E.		......	......	......		......	......	......		Reinecke and Tunker.
Kauine Noss	68 39	43 32	1828·5	4 00 E.	1 27 E.	5·5 E.		......	......	......		......	......	......		Reinecke.
			1841·5	4 09 E.	0 06 E.	4·3 E.	5·0 E.	75 54	......	76·0	76·0	11·70	......	11·70	11·51	Sawalief.
			1870·5	8 04 E.	2 54 W.	5·2 E.		76 08	......	......		11·39	......	11·39		Belavenetz.
Kandalaksha River ...	65 45	43 43	1830·5	3 45 E.	1 14 E.	5·0 E.		......	......	......		......	......	......		Krotoff.
River Kouloi............	66 12	43 46	1830·0	3 15 E.	1 17 E.	4·5 E.	4·5 E.	......	......	......	75·0	11·62	......	11·62		Krotoff.
			1841·5	......	......	......		75 01	......	75·0						Sawalief.
Cape Karushin	67 12	43 48	1830·5	3 45 E.	1 14 E.	5·0 E.		......	......	......		......	......	......		Krotoff.
Mesen......................	65 50	44 16	1830·0	3 10 E.	1 17 E.	4·5 E.	4·2 E.	......	......	......	74·1	11·54	......	11·54		Krotoff.
			1841·5	3 53 E.	0 06 E.	4·0 E.		74 07	......	74·1						Sawalief.
Kambalniza River......	68 19	45 57	1841·5	......	......	......		75 39	......	75·7		......	......	......		Sawalief.
Schemtschusnaia River	67 49	46 22	1841·5	5 50 E.	0 06 E.	5·9 E.		75 42	......	75·7		11·55	......	11·55		Sawalief.
At sea......................	69 45	47 00	1824·5	5 10 E.	1 52 E.	7·0 E.		......	......	......		......	......	......		Lütke.
Gussinaia River	69 26	49 00	1841·5	......	......	......		76 40	......	76·7		......	......	......		Sawalief.
Waaskina River	68 43	49 05	1841·5	......	......	......		76 19	......	76·3		12·01	......	12·01		Sawalief.
Indega River............	67 39	49 15	1841·5	7 25 E.	0 06 E.	7·5 E.		75 33	......	75·6		11·36	......	11·36		Sawalief.
Pustozersk..............	67 30	52 34	1848·0	9 47 E.	0 34 W.	9·2 E.		75 38	......	75·6		......	......	......		Kovalski.
At sea......................	69 40	52 45	1824·5	9 52 E.	1 52 E.	11·7 E.		......	......	......		......	......	......		Lütke.
At sea......................	69 45	53 15	1824·5	9 19 E.	1 52 E.	11·2 E.		......	......	......		......	......	......		Lütke.
Costianoi Noss	68 19	53 48	1824·5	9 35 E.	1 58 E.	11·5 E.		......	......	......		......	......	......		Ivanhoff and Pakhtussoff.
Petchora River	68 37	56 42	1823·5	9 03 E.	1 52 E.	11·0 E.		......	......	......		......	......	......		Lütke.

ZONE VI.—Lat. 65° to 70° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.	Inclination. Observed.	Inclination. Cor. to Epoch 1842·5.	Inclination. Corrected.	Force in British units. Observed.	Force in British units. Cor. to Epoch 1842·5.	Force in British units. Corrected.	Observers.
	° ′	° ′		° ′	° ′	°	° ′	′	°				
Mouth of Potchora ...	68 53	53 52	1821·5	11 57 E.	1 52 E.	13·5 E.	......	......	......	......	......	......	Rogozine.
Perevoznoi Noss	68 47	57 05	1821·5	11 00 E.	1 52 E.	12·9 E.	......	......	......	......	......	......	Rogozine.
Sinkine Noss..........	68 42	57 35	1821·5	11 12 E.	1 52 E.	13·1 E.	......	......	......	......	......	......	Rogozine.
Tugorski Schar.........	68 59	59 27	1823·5	9 05 E.	1 58 E.	11·1 E.	......	......	......	......	......	......	Lütke.
Nikolskaia River	69 40	60 40	1821·5	10 08 E.	1 52 E.	12·0 E.	......	......	......	......	......	......	Lütke.
[illegible]	[illegible] 03	64 59	1828·5	......	......	......	75 15	− 2	75·2	11·98	+·01	11·99	Erman.
[illegible]	[illegible] 30	65 39	1828·5	......	......	......	75 59	− 2	76·0	12·19	+·01	12·20	Erman.
Erman (Mean Position)	66 31	66 36	1848·5	16 33 E.	0 37 W.	15·9 E.	76 08	− 1	76·1	......	......	......	Kovalski.
O[illegible]	[illegible] 31	66 42	1829·0	14 33 E.	2 10 E.	16·7 E.	76 07	− 1	76·1	12·07	+·01	12·08	Erman.
[illegible]	[illegible] 55	87 38	1829·5	15 00 E.	2 20 E.	17·3 E.	77 46	+11	78·0	12·78	+·05	12·83	Hansteen.
[illegible]	[illegible] 47	87 43	1835·5	16 21 E.	1 10 E.	17·5 E.	77 49	+ 5	77·9	......	......	......	Fedorow.
[illegible]	[illegible] 00	87 54	1829·5	14 38 E.	2 20 E.	17·0 E.	77 20	+11	77·5	12·82	+·05	12·87	Hansteen.
[illegible]	[illegible] 03	87 57	1829·5	......	......	......	77 34	+11	77·8	12·86	+·05	12·91	Hansteen.
[illegible]	[illegible] 48	88 15	1829·5	......	......	......	77 46	+12	78·0	12·77	+·05	12·82	Hansteen.
[illegible]	[illegible] 43	122 39	1822·5	0 40 E.	2 35 E.	3·3 E.	......	......	......	......	......	......	Wrangel & Anjou.
Pastgdom	67 18	122 41	1822·5	1 00 W.	2 35 E.	1·6 E.	......	......	......	......	......	......	Wrangel & Anjou.
Schingansk	66 46	122 53	1822·5	2 15 W.	2 34 E.	0·3 E.	78 06	+33	78·6	......	......	......	Wrangel & Anjou.
Deshatalak [illegible]	68 25	123 54	1822·5	1 00 E.	2 31 E.	3·5 E.	......	......	......	......	......	......	Wrangel & Anjou.
[illegible]	[illegible] 38	125 54	1822·5	3 00 E.	2 25 E.	5·4 E.	......	......	......	......	......	......	Wrangel & Anjou.
[illegible]	[illegible] 51	132 17	1822·5	......	......	......	77 06	+35	77·7	......	......	......	Wrangel & Anjou.
[illegible]	[illegible] 34	133 50	1822·5	......	......	......	77 55	+35	78·5	......	......	......	Wrangel & Anjou.
Kuuju	67 59	134 13	1822·5	......	......	......	78 26	+35	79·0	......	......	......	Wrangel & Anjou.
Schanki	69 43	135 20	1822·5	......	......	......	79 15	+35	79·8	......	......	......	Wrangel & Anjou.
[illegible]	[illegible] 26	160 16	1821·5	11 45 E.	1 32 E.	13·3 E.	......	......	......	......	......	......	Wrangel & Anjou.
[illegible]	[illegible] 32	160 40	1821·0	9 56 E.	1 29 E.	11·4 E.	77 28	+31	78·0	......	......	......	Wrangel.
[illegible]	[illegible] 42	160 51	1821·5	12 30 E.	1 28 E.	14·0 E.	......	......	......	......	......	......	Wrangel.
Pochodsk	69 04	160 55	1821·5	11 45 E.	1 28 E.	13·2 E.	......	......	......	......	......	......	Wrangel.
Station	68 57	161 15	1822·5	12 30 E.	1 25 E.	13·9 E.	......	......	......	......	......	......	Wrangel.
Suchanoi Island	69 31	161 43	1822·5	13 30 E.	1 22 E.	14·9 E.	......	......	......	......	......	......	Wrangel.
Station	69 18	162 03	1822·5	15 30 E.	1 20 E.	16·8 E.	......	......	......	......	......	......	Wrangel.
Station	69 05	162 09	1822·5	15 00 E.	1 19 E.	16·3 E.	......	......	......	......	......	......	Wrangel.
Station	68 53	162 09	1822·5	13 00 E.	1 19 E.	14·3 E.	......	......	......	......	......	......	Wrangel.
Lobasnoie	67 03	162 20	1821·5	13 30 E.	1 18 E.	14·8 E.	......	......	......	......	......	......	Wrangel.
Little Baranow	69 38	162 27	1821·5	12 30 E.	1 16 E.	13·8 E.	78 06	+30	78·6	......	......	......	Wrangel.
Station	69 38	162 48	1822·5	12 05 E.	1 14 E.	13·3 E.	......	......	......	......	......	......	Wrangel.
Plotbischtsche	68 01	162 55	1821·5	14 30 E.	1 13 E.	15·7 E.	......	......	......	......	......	......	Wrangel.
Station	69 42	163 19	1822·5	13 00 E.	1 11 E.	14·2 E.	......	......	......	......	......	......	Wrangel.
Station	69 44	163 51	1822·5	12 35 E.	1 09 E.	13·7 E.	......	......	......	......	......	......	Wrangel.
Great Baranow	69 41	163 52	1822·5	13 30 E.	1 08 E.	14·6 E.	......	......	......	......	......	......	Wrangel.
North of Little Anini..	69 24	164 02	1822·5	12 45 E.	1 07 E.	13·9 E.	......	......	......	......	......	......	Wrangel.
Station	69 44	164 10	1822·5	12 35 E.	1 05 E.	13·7 E.	......	......	......	......	......	......	Wrangel.
Station	69 36	164 32	1822·5	13 30 E.	1 03 E.	14·6 E.	......	......	......	......	......	......	Wrangel.
River Pogindena	68 37	164 43	1822·5	14 00 E.	1 04 E.	15·1 E.	......	......	......	......	......	......	Wrangel.
Station	68 47	165 11	1822·5	15 00 E.	1 01 E.	16·0 E.	......	......	......	......	......	......	Wrangel.
Station	68 37	165 12	1822·5	14 00 E.	1 01 E.	15·0 E.	......	......	......	......	......	......	Wrangel.
On the Coast............	69 30	166 21	1822·5	15 26 E.	0 53 E.	16·3 E.	......	......	......	......	......	......	Wrangel.
Station	69 09	166 29	1822·5	15 00 E.	0 51 E.	15·9 E.	......	......	......	......	......	......	Wrangel.
On the Tundra	69 23	166 31	1822·5	14 59 E.	0 51 E.	15·8 E.	......	......	......	......	......	......	Wrangel.
Balagan	69 31	166 40	1822·5	15 25 E.	0 50 E.	16·3 E.	......	......	......	......	......	......	Wrangel.
Station	69 43	167 30	1821·5	18 30 E.	0 47 E.	19·3 E.	......	......	......	......	......	......	Wrangel.
Cape Matiushkin	69 45	170 47	1821·5	18 00 E.	0 37 E.	18·6 E.	......	......	......	......	......	......	Wrangel.
Werkon River	69 53	173 32	1823·5	18 57 E.	0 18 E.	19·3 E.	79 59	+28	80·5	......	......	......	Wrangel.
East of Cape Jakan ...	69 36	176 58	1823·5	21 30 E.	0 12 W.	21·3 E.	......	......	......	......	......	......	Wrangel.
North Cape	68 55	179 56	1823·5	21 40 E.	0 29 W.	21·2 E.	......	......	......	......	......	......	Wrangel.
Holy Cross Bay	65 28	181 28	1828·5	21 01 E.	0 18 W.	20·8 E.	75 43	+18	76·0	12·80	......	12·80	Lütke.
At sea, mean of two observations	65 11	183 17	1828·5	19 15 E.	......	19·3 E.	......	......	......	......	......	......	Lütke.
Wankarem River	67 43	183 33	1823·5	23 00 E.	0 24 W.	22·6 E.	......	......	......	......	......	......	Wrangel.
Koliutschin Island ...	67 27	184 25	1823·5	23 26 E.	0 24 W.	23·0 E.	......	......	......	......	......	......	Wrangel.
At sea....................	69 28	184 50	1849·5	25 03 E.	......	25·1 E.	......	......	......	......	......	......	Kellett.
At sea....................	69 26	185 00	1849·5	26 12 E.	......	26·2 E.	......	......	......	......	......	......	Kellett.
At sea....................	69 54	185 38	1849·5	27 41 E.	......	27·7 E.	......	......	......	......	......	......	Kellett.
At sea....................	69 47	187 13	1849·5	27 45 E.	......	27·8 E.	......	......	......	......	......	......	Kellett.

ZONE VI.—Lat. 65° to 70° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction: to Epoch 1842·5.	Declination. Corrected.		Inclination. Observed.	Inclination. Cor. to Epoch 1842·5.	Inclination. Corrected.		Force in British units. Observed.	Force. Cor. to Epoch 1842·5.	Force. Corrected.	Observers.
	° ′	° ′		° ′		°		° ′		°					
Laureme	65 32	188 20	1819·5	......	......	......		77 15	......	77·3		......	......	......	Moore.
At sea	65 11	189 07	1850·5	......	......	......		76 00	......	76·0		......	......	......	Collinson.
[illegible]	65 29	189 10	1819·5	......	......	......		76 17	......	76·3		......	......	......	Moore.
Bay of St. Lawrence	65 38	189 14	1828·5	24 01 E.	......	24·1 E.		76 36	......	76·6		12·84	......	12·84	Lütke.
Mean of 2 Stations	65 37	189 20	1819·5	......	......	......		76 37	......	76·6		......	......	......	Moore.
Chagneen	65 45	189 30	1819·5	......	......	......		76 56	......	76·9		......	......	......	Moore.
At sea	69 36	189 45	1819·5	30 42 E.	......	30·7 E.		......	......	......		......	......	......	Kellett.
At sea	65 50	190 03	1819·5	24 07 E.	......	24·1 E.		......	......	......		......	......	......	Kellett.
At sea	66 20	190 34	1850·5	26 06 E.	......	26·1 E.		......	......	......		......	......	......	Kellett.
At sea	66 01	190 54	1850·5	......	......	......		76 53	......	76·9		......	......	......	Collinson.
At sea	66 49	191 34	1850·5	26 01 E.	......	26·0 E.		......	......	......		......	......	......	Kellett.
At sea	67 55	192 33	1850·5	27 03 E.	......	27·1 E.		......	......	......		......	......	......	Kellett.
At sea	66 57	192 35	1851·0	26 28 E.	......	26·5 E.		......	......	......		......	......	......	Collinson.
At sea	67 01	192 41	1850·5	25 17 E.	......	25·3 E.		......	......	......		......	......	......	Collinson.
At sea	68 08	192 58	1850·5	26 00 E.	......	26·0 E.		......	......	......		......	......	......	Kellett.
At sea	69 17	193 11	1819·5	30 00 E.	......	30·0 E.		......	......	......		......	......	......	Kellett.
At sea	68 33	193 31	1819·5	30 46 E.	......	30·8 E.		......	......	......		......	......	......	Kellett.
At anchor	68 38	193 40	1819·5	31 35 E.	......	31·6 E.		......	......	......		......	......	......	Kellett.
At sea	68 51	193 40	1850·5	31 10 E.	......	31·2 E.		......	......	......		......	......	......	Collinson.
Port Clarence and Grantley Bay	65 17	193 41	1827·5	26 55 E.	......	26·9 E.	26·4 E.	......	......	......	76·6	......	......	......	Beechey.
			1850·5	26 26 E.	......	26·4 E.		......	......	......		......	......	......	Kellett.
			1850·5	......	......	......		75 48	......	75·8		......	......	......	Collinson.
			1851·5	26 00 E.	......	26·0 E.		76 30	......	76·5		......	......	......	Maguire.
			1851·5	......	......	......		77 26	......	74·4		......	......	......	Collinson.
At sea	68 42	193 44	1819·5	29 56 E.	......	29·9 E.		......	......	......		......	......	......	Kellett.
At sea	67 58	193 45	1851·5	29 46 E.	......	29·8 E.		......	......	......		......	......	......	Collinson.
At sea	68 38	193 53	1851·5	31 08 E.	......	31·1 E.		......	......	......		......	......	......	Collinson.
At sea	69 07	194 13	1849·5	32 00 E.	......	32·0 E.		......	......	......		......	......	......	Kellett.
At sea	69 52	195 23	1819·5	32 59 E.	......	33·0 E.		......	......	......		......	......	......	Kellett.
Cape of Good Hope	66 03	195 30	1826·5	29 28 E.	......	29·5 E.		......	......	......		......	......	......	Beechey.
At sea	66 48	196 14	1819·5	29 59 E.	......	30·0 E.		......	......	......		......	......	......	Kellett.
At sea	69 11	196 16	1851·0	30 15 E.	......	30·2 E.		......	......	......		......	......	......	Collinson.
Cape Krusenstern	67 11	196 23	1826·5	30 12 E.	......	30·2 E.		......	......	......		......	......	......	Beechey.
At sea	66 56	196 29	1849·5	29 33 E.	......	29·6 E.		......	......	......		......	......	......	Kellett.
Cape Deceit	66 06	197 21	1826·5	30 18 E.	......	30·3 E.		......	......	......		......	......	......	Beechey.
Chamisso Island	66 16	198 12	1826·5	28 53 E.	......	28·9 E.	29·6 E.	......	......	......		......	......	......	Beechey.
			1819·5	30 26 E.	......	30·4 E.		......	......	......		......	......	......	Kellett.
Point Demarcation	69 41	219 00	1837·5	48 23 E.	......	48·4 E.		......	......	......		......	......	......	Simpson.
Clarence Bay	69 38	219 09	1826·5	45 43 E.	......	45·7 E.		83 27	......	83·5		......	......	......	Franklin.
Herschel Island	69 36	220 18	1826·5	46 13 E.	......	46·2 E.		......	......	......		......	......	......	Franklin.
Babbage River	69 19	221 50	1826·5	46 16 E.	......	46·3 E.		......	......	......		......	......	......	Franklin.
Point Kay	69 18	221 52	1837·5	49 00 E.	......	49·0 E.		......	......	......		......	......	......	Simpson.
Richardson's Chain	69 01	222 35	1826·5	46 41 E.	......	46·7 E.		82 22	......	82·4		......	......	......	Franklin.
Shoal Water Bay	68 51	223 39	1837·5	45 47 E.	......	49·4 E.		......	......	......		......	......	......	Simpson.
At sea (2 Stations)	69 53	224 24	1851·5	48 55 E.	......	48·9 E.		83 22	......	83·4		......	......	......	Collinson.
Red River	67 27	226 24	1826·5	45 37 E.	......	45·6 E.		82 36	......	82·6		......	......	......	Franklin.
At sea	69 49	227 02	1851·5	......	......	......		83 10	......	83·2		......	......	......	Collinson.
Fort Good Hope	66 16	231 30	1837·5	44 12 E.	......	43·5 E.		......	......	......		......	......	......	Simpson.
			1844·5	42 46 E.	......			82 56	......	82·9		13·64	......	13·64	Lefroy.
Cape Parry	69 58	236 37	1826·5	55 47 E.	......	55·8 E.		......	......	......		......	......	......	Franklin.
Clapperton Island	69 42	236 43	1826·5	54 00 E.	......	54·0 E.		......	......	......		......	......	......	Franklin.
Fort Franklin	65 12	236 47	1826·5	39 00 E.	......	39·0 E.		82 58	......	83·0		......	......	......	Franklin.
Fort Confidence	66 54	241 11	1837·5	48 30 E.	......	49·6 E.		84 48	......	84·8		......	......	......	Simpson.
			1849·5	50 42 E.	......			84 51	......			......	......	......	Richardson.
Station	67 11	242 42	1849·5	50 49 E.	......	50·8 E.		......	......	......		......	......	......	Rae.
Kendall River	67 11	242 55	1837·5	49 30 E.	......	49·5 E.		......	......	......		......	......	......	Simpson.
Mouth of Kendall River	67 07	243 39	1837·5	48 00 E.	......	48·0 E.		......	......	......		......	......	......	Simpson.
Mouth of Richardson's River	67 54	244 04	1839·5	52 10 E.	......	52·2 E.		......	......	......		......	......	......	Simpson.
Bloody Fall	67 43	244 10	1838·5	54 17 E.	......	54·3 E.		......	......	......		......	......	......	Simpson.
Mouth of Coppermine River	68 48	244 29	1838·5	53 48 E.	......	53·8 E.		......	......	......		......	......	......	Simpson.

ZONE VI.—Lat. 65° to 70° N. (continued).

[illegible]	[illegible]	[illegible]	[illegible]				[illegible]		[illegible]				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]							
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]							
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]							
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]							[illegible]
Cape Barrow	68 04	249 00	1839·5	......	......	......	87 13	......	87·2	......	......	......	Simpson.
Moore's Bay	67 44	250 00	1838·5	48 00 E.	......	48·0 E.	......	......	......	......	......	......	Simpson.
Boat Haven	68 16	250 39	1838·5	46 00 E.	......	46·0 E.	......	......	......	......	......	......	Simpson.
Victoria Land	68 57	252 00	1839·5	57 40 E.	......	57·7 E.	......	......	......	......	......	......	Simpson.
Cape Alexander	68 56	253 20	1839·5	62 10 E.	......	62·2 E.	88 15	......	88·3	......	......	......	Simpson.
Trap Cape	68 52	253 40	1838·5	63 00 E.	......	63·0 E.	......	......	......	......	......	......	Simpson.
Simpson's Farthest	68 44	253 57	1838·5	60 38 E.	......	60·6 E.	......	......	......	......	......	......	Simpson.
On ice	68 54	256 12	1853·5	......	......	......	89 08	......	89·1	......	......	......	Collinson.
White Bear Point	68 07	256 23	1839·5	54 45 E.	......	54·8 E.	88 20	......	88·3	......	......	......	Simpson.
On ice	68 35	257 45	1853·5	......	......	......	89 40	......	89·7	......	......	......	Collinson.
On shore	68 45	257 57	1853·5	......	......	......	89 40	......	89·7	......	......	......	Collinson.
On shore	69 33	258 51	1853·5	......	......	......	89 28	......	89·5	......	......	......	Collinson.
On ice	69 43	258 56	1853·5	......	......	......	89 22	......	89·4	......	......	......	Collinson.
On shore	69 56	259 05	1853·5	......	......	......	89 14	......	89·2	......	......	......	Collinson.
King William's Land	69 08	259 55	1859·5	......	......	......	89 26	......	89·4	......	......	......	McClintock.
Point Victory	69 37	261 19	1859·5	......	......	......	89 45	......	89·8	......	......	......	McClintock.
Cape Herschel	68 41	261 38	1839·5	......	......	......	89 29	......	89·5	......	......	......	Simpson.
Rock Rapid	65 54	261 50	1834·5	29 16 E.	......	29·3 E.	87 40	......	87·7	......	......	......	Back.
South of Cape Herschel	68 42	261 50	1859·5	......	......	......	89 35	......	89·6	......	......	......	McClintock.
Station	68 33	262 00	1839·5	45 00 E.	......	45·0 E.	......	......	......	......	......	......	Simpson.
[illegible]	68 21	262 35	1839·5	......	......	......	89 30	......	89·5	......	......	......	Simpson.
[illegible]	[illegible] 41	262 50	1859·5	......	......	......	89 55	......	89·9	......	......	......	McClintock.
[illegible]	68 31	262 50	1859·5	......	......	......	89 24	......	89·4	......	......	......	McClintock.
[illegible]	67 50	263 23	1859·5	......	......	......	89 32	......	89·5	......	......	......	McClintock.
[illegible]	[illegible] 58	263 40	1859·5	......	......	......	89 08	......	89·1	......	......	......	McClintock.
[illegible]	[illegible] 32	263 50	1859·5	......	......	......	89 51	......	89·9	......	......	......	McClintock.
[illegible]	[illegible] 47	261 42	1834·5	......	......	......	87 36	......	87·6	......	......	......	Back.
Point Beaufort	67 41	264 58	1834·5	......	......	......	88 03	......	88·1	......	......	......	Back.
Point Ogle	68 14	265 02	1834·5	......	......	......	89 24	......	89·4	......	......	......	Back.
On land or ice	69 35	265 07	1831·5	57 15 W.	......	57·3 W.	89 42	......	89·7	......	......	......	Ross.
Cape Isabella	69 26	266 09	1831·5	......	......	......	89 22	......	89·4	......	......	......	Ross.
[illegible]	69 30	[illegible] 32	1831·5	......	......	......	89 17	......	89·3	......	......	......	Ross.
Fort Hope	66 32	273 04	1847·5	62 50 W.	......	62·8 W.	......	......	......	......	......	......	Rae.
Repulse Bay	66 31	273 30	1821·5	48 33 W.	......	48·6 W.	88 07	......	88·1	......	......	......	Parry and Fisher.
Southampton Island	[illegible] 30	271 45	1821·5	47 07 W.	......	47·1 W.	87 28	......	87·5	......	......	......	Parry and Fisher.
York Bay	[illegible] 27	274 45	1821·5	47 34 W.	......	47·6 W.	......	......	......	......	......	......	Parry.
On a Shoal	65 21	275 03	1821·5	46 41 W.	......	46·7 W.	......	......	......	......	......	......	Parry.
Duckett Cove	66 13	275 20	1821·5	52 20 W.	......	52·3 W.	87 31	......	87·5	......	......	......	Parry and Fisher.
Cape Welsford	65 28	275 20	1821·5	50 18 W.	......	50·3 W.	......	......	......	......	......	......	Parry.
Gore Bay	66 24	275 20	1821·5	56 20 W.	......	56·3 W.	......	......	......	......	......	......	Parry.
On ice	65 34	275 41	1821·5	50 34 W.	......	50·6 W.	......	......	......	......	......	......	Parry.
Lyon Inlet	66 38	275 49	1821·5	54 00 W.	......	54·0 W.	87 52	......	87·9	......	......	......	Parry and Fisher.
Safety Cove	66 32	276 11	1821·5	54 46 W.	......	54·8 W.	......	......	......	......	......	......	Parry and Fisher.
On ice	69 48	276 31	1822·5	89 18 W.	......	89·3 W.	88 21	......	88·4	......	......	......	Parry and Fisher.
On ice	65 31	276 40	1821·5	53 49 W.	......	53·8 W.	......	......	......	......	......	......	Parry and Fisher.
Winter Island	66 12	277 06	1822·5	57 24 W.	......	57·4 W.	87 51	......	87·9	......	......	......	Parry and Fisher.
On ice	65 27	278 03	1821·5	55 06 W.	......	55·1 W.	......	......	......	......	......	......	Parry and Fisher.
On ice	69 36	278 05	1822·5	88 51 W.	......	88·9 W.	......	......	......	......	......	......	Parry and Fisher.
On ice	66 56	278 21	1822·5	62 17 W.	......	62·3 W.	87 47	......	87·8	......	......	......	Parry and Fisher.
On ice	69 32	278 23	1822·5	87 20 W.	......	87·3 W.	......	......	......	......	......	......	Parry and Fisher.
Igloolik	69 21	278 23	1822·5	83 01 W.	......	83·0 W.	88 10	......	88·2	12·43	......	12·43	Parry and Fisher.
On shore	67 03	278 32	1822·5	65 13 W.	......	65·2 W.	......	......	......	......	......	......	Parry and Fisher.
On shore	67 11	278 36	1822·5	70 28 W.	......	70·5 W.	......	......	......	......	......	......	Parry and Fisher.
On ice	69 32	278 37	1822·5	86 06 W.	......	86·1 W.	88 06	......	88·1	......	......	......	Parry and Fisher.
On ice	69 31	278 46	1822·5	82 32 W.	......	82·5 W.	87 37	......	87·6	......	......	......	Parry and Fisher.
On ice	69 33	278 49	1822·5	82 22 W.	......	82·4 W.	......	......	......	......	......	......	Parry and Fisher.
On ice	69 24	279 58	1822·5	79 21 W.	......	79·4 W.	......	......	......	......	......	......	Parry and Fisher.
On ice	65 08	280 25	1821·5	52 12 W.	......	52·2 W.	87 09	......	87·2	......	......	......	Parry and Fisher.

ZONE VI.—Lat. 65° to 70° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.	Inclination. Observed.	Inclination. Cor. to Epoch 1842·5.	Inclination. Corrected.	Force in British units. Observed.	Force. Cor. to Epoch 1842·5.	Force. Corrected.	Observers.
	° ′	° ′		° ′		°	° ′		°				
Ice in Davis Strait ...	68 30	295 12	1820·5	......	......	......	84 21	......	84·4	......	......	......	Sabine.
Baffin's Bay, on ice ...	66 50	301 09	1858·5	71 32 w.	......	71·5 w.	......	......	......	......	......	......	McClintock.
Baffin's Bay, on ice ...	67 18	301 25	1858·5	72 00 w.	......	72·0 w.	......	......	......	......	......	......	McClintock.
Baffin's Bay, on ice ...	68 17	301 28	1858·5	73 31 w.	......	73·5 w.	......	......	......	......	......	......	McClintock.
Baffin's Bay, on ice ...	66 26	301 30	1858·5	69 55 w.	......	69·9 w.	......	......	......	......	......	......	McClintock.
Baffin's Bay, on ice ...	66 39	301 40	1858·5	71 38 w.	......	71·6 w.	......	......	......	......	......	......	McClintock.
Baffin's Bay, on ice ...	65 57	304 04	1857·5	58 00 w.	......	58·0 w.	......	......	......	......	......	......	R. C. Allen.
Baffin's Bay, on ice ...	68 14	305 45	1818·5	67 52 w.	......	67·9 w.	......	......	......	......	......	......	Sabine.
Baffin's Bay, on ice ...	68 23	306 13	1818·5	67 32 w.	......	67·5 w.	83 08	......	83·1	12·27	......	12·27	Sabine.
Greenland ...	66 57	306 26	1836·5	......	......	......	82 51	......	82·9	......	......	......	James Ross.
[illegible]	[illegible]	306 30	1853·5	......	......	......	81 48	......	81·8	12·22	......	12·22	Bellot.
[illegible]	[illegible]	306 31	1852·5	......	......	......	82 53	......	82·9	......	......	......	Inglefield.
Godhavn	69 12	306 32	1861·5	......	......	......	81 51	......	81·9	12·43	......	12·43	Hayes.
Whale-fish Islands ...	68 59	306 42	1824·5	70 24 w.	......	70·4 w.	82 54	−18	82·6	......	......	......	Parry.
			1836·5	......	......	......	82 23	− 6	82·3	......	......	......	James Ross.
			1848·5	......	......	......	82 24	+ 6	82·5	......	......	......	[illegible]
			1850·5	......	......	...... } 71·6 w.	82 12	+ 8	82·3 } 82·4	......	......	......	[illegible]
			1851·5	......	......	......	......	......	......	12·15	......	12·15	Ommanney.
			1852·5	70 47 w.	......	70·8 w.	82 10	+10	82·3	......	......	......	Belcher.
			1858·5	73 28 w.	......	73 5 w.	......	......	......	......	......	......	McClintock.
Holsteinborg	66 52	306 44	1853·5	......	......	......	82 16	......	82·3	12·44	......	12·44	Bellot.
On ice	69 24	308 14	1857·5	72 00 w.	......	72·0 w.	......	......	......	......	......	......	R. C. Allen.
Grah Island	65 20	321 20	1829·5	54 26 w.	......	54·4 w.	......	......	......	......	......	......	Graah.
[illegible]	65 24	345 12	1833·5	......	......	......	77 13	......	77·2 } 77·0	11·61	......	11·61 } 11·31	Blosseville.
[illegible]	65 10	346 21	1833·5	......	......	......	76 46	......	76·8	11·01	......	11·01	Blosseville.

ZONE VII.—LATITUDE 70° TO 75° N.

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M'Clintock
Allen ....
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Bellot ....
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(Omitted in Zone VI.)

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ZONE VII.—Lat. 70° to 75° N.

[illegible]	[illegible]	[illegible]	[illegible]	Declination.				Inclination.				Force in British units.				Observers.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		Lemström.
[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		Keilhau.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		Gaimard.
			[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]		[illegible]		Sabine.
			[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]						"
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	
			[illegible]					[illegible]	[illegible]	[illegible]		[illegible]		[illegible]		
			[illegible]					[illegible]	[illegible]	[illegible]		[illegible]		[illegible]		Kämtz.
			[illegible]	[illegible]	?	[illegible]		[illegible]				[illegible]		[illegible]		Belavenetz.
[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]		[illegible]		[illegible]		Keilhau.
			[illegible]					[illegible]	[illegible]	[illegible]		[illegible]		[illegible]		Keilhau.
[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	11·13	Gaimard.
			[illegible]					[illegible]	[illegible]	[illegible]		[illegible]		[illegible]		Kämtz.
[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]		[illegible]		[illegible]		Gaimard.
[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	11·25	Keilhau.
			[illegible]					[illegible]	[illegible]	[illegible]		[illegible]		[illegible]		Kämtz.
[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]		[illegible]		[illegible]		Keilhau.
[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]		[illegible]		[illegible]		Keilhau.
[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]		[illegible]		[illegible]		Keilhau.
[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]		[illegible]		[illegible]		Keilhau.
[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]		[illegible]		[illegible]		Keilhau.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]						Reinecke.
[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	11·06	Keilhau.
			[illegible]					[illegible]	[illegible]	[illegible]		[illegible]		[illegible]		Reinecke.
			[illegible]					[illegible]	[illegible]	[illegible]		[illegible]		[illegible]		Keilhau.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	11·20	Reinecke.
			[illegible]	[illegible]				[illegible]				[illegible]		[illegible]		Belavenetz.
[illegible]	[illegible] 13	[illegible]	[illegible]	[illegible]		[illegible]										Lütke.
At sea	73 30	41 20	1824·5	5 38 E.	......	5·6 E.		......	......	......		......	......	......		Lütke.
At sea	74 10	41 35	1824·5	6 46 E.	......	6·8 E.		......	......	......		......	......	......		Lütke.
At sea	73 50	46 00	1824·5	6 38 E.	......	6·6 E.		......	......	......		......	......	......		Lütke.
At sea	74 32	46 00	1824·5	6 54 E.	......	6·9 E.		......	......	......		......	......	......		Lütke.
At sea	71 57	46 26	1824·5	7 00 E.	......	7·0 E.		......	......	......		......	......	......		Lütke.
At sea	74 55	46 29	1824·5	8 30 E.	......	8·5 E.		......	......	......		......	......	......		Lütke.
At sea	74 55	49 45	1824·5	9 13 E.	......	9·2 E.		......	......	......		......	......	......		Lütke.
At sea	71 30	49 55	1824·5	6 49 E.	......	6·8 E.		......	......	......		......	......	......		Lütke.
At sea	72 16	50 23	1822·5	9 00 E.	......	9·0 E.		......	......	......		......	......	......		Lütke.
At sea	71 28	50 52	1822·5	9 00 E.	......	9·0 E.		......	......	......		......	......	......		Lütke.
At sea	71 48	51 03	1822·5	9 00 E.	......	9·0 E.		......	......	......		......	......	......		Lütke.
At sea	72 03	51 12	1822·5	9 00 E.	......	9·0 E.		......	......	......		......	......	......		Lütke.
At sea	70 29	51 44	1824·5	11 00 E.	......	11·0 E.		......	......	......		......	......	......		Lütke.
At sea	70 30	52 00	1824·5	9 29 E.	......	9·5 E.		......	......	......		......	......	......		Lütke.
At sea	73 17	52 45	1824·5	11 30 E.	......	11·5 E.		......	......	......		......	......	......		Lütke.
Kostin Schar	71 17	53 30	1837·5	......	......	......		78 16	− 4	78·2		11·00	......	11·09		Ziwolka.
Moller's Bay	72 31	53 30	1839·5	11 32 E.	0 19 E.	11·9 E.		78 16	− 2	78·2		......	......	......		Pakhtussoff.
At sea	70 25	53 40	1824·5	8 53 E.	......	8·9 E.		......	......	......		......	......	......		Lütke.
Matotchua Strait	73 16	54 00	1822·5	11 41 E.	2 04 E.	13·8 E.	12·9 E.	......	......	......	79·1	......	......	......		Lütke.
			1834·5	12 00 E.	0 52 E.	12·9 E.		79 04	− 6			......	......	......		Pakhtussoff.
Matotchua Strait	73 20	54 20	1823·5	10 30 E.	2 03 E.	12·6 E.		78 47	−14			......	......	......		Lütke.
Thirakina River	73 18	54 21	1835·5	11 50 E.	0 45 E.	12·6 E.		79 42	− 5			......	......	......		Pakhtussoff.
Nova Zembla	73 57	54 30	1839·5	12 20 E.	0 19 E.	12·7 E.		79 17	− 2			......	......	......		Ziwolka.
At sea	70 30	55 25	1824·5	8 31 E.	......	8·5 E.		......	......	......		......	......	......		Lütke.
Lütke Bay	72 26	55 28	1833·5	10 46 E.	0 56 E.	11·7 E.		......	......	......		......	......	......		Pakhtussoff.
Maschigin Inlet	74 44	55 50	1839·5	13 50 E.	0 19 E.	14·2 E.		80 14	− 2	80·2		......	......	......		Ziwolka.
At sea	70 25	55 50	1824·5	13 22 E.	......	13·4 E.		......	......	......		......	......	......		Lütke.
Cape Drovianoi	73 15	56 18	1835·5	11 20 E.	0 45 E.	12·1 E.		......	......	......		......	......	......		Pakhtussoff.
Petoukhof Char	70 34	56 28	1832·5	11 24 E.	1 05 E.	12·5 E.		......	......	......		......	......	......		Pakhtussoff.
Cape Bik	73 14	56 29	1835·5	11 10 E.	0 45 E.	11·9 E.		......	......	......		......	......	......		Pakhtussoff.
At sea	70 15	56 30	1824·5	11 54 E.	......	11·9 E.		......	......	......		......	......	......		Lütke.
Matoschin Strait	73 18	56 30	1835·5	11 21 E.	0 45 E.	12·1 E.		......	......	......		......	......	......		Pakhtussoff.
At sea	70 05	57 30	1824·5	12 12 E.	......	12·2 E.		......	......	......		......	......	......		Lütke.
Kaminka Bay	70 36	57 31	1833·5	11 47 E.	0 56 E.	12·7 E.		......	......	......		......	......	......		Pakhtussoff.

ZONE VII.—Lat. 70° to 75° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.	Inclination. Observed.	Inclination. Cor. to Epoch 1842·5.	Inclination. Corrected.	Force in British units. Observed.	Force in British units. Cor. to Epoch 1842·5.	Force in British units. Corrected.	Observers.
	° ′	° ′		° ′	° ′	°	° ′	′	°				
Cape Muller	73 37	57 40	1835·5	13 50 E.	0 45 E.	14·6 E.	......	......	......	......	......	......	Pakhtussoff.
At sea	70 25	57 45	1824·5	12 48 E.	1 52 E.	14·7 E.	......	......	......	......	......	......	Lütke.
At sea	70 25	58 17	1824·5	11 00 E.	1 52 E.	12·9 E.	......	......	......	......	......	......	Lütke.
[illegible] Bay	71 07	58 30	1835·5	14 50 E.	0 45 E.	15·6 E.	......	......	......	......	......	......	Pakhtussoff.
Pakhtussoff Island	71 24	59 25	1835·5	14 10 E.	0 45 E.	14·9 E.	......	......	......	......	......	......	Pakhtussoff.
R. Taimyr S. Mylla	73 50	93 27	1843·5	......	......	......	82 12	......	82·2	......	......	......	Middendorf.
[illegible]	71 05	94 52	1843·5	......	......	......	81 27	......	81·5	......	......	11·99	Middendorf.
River [illegible]	72 07	95 29	1843·5	......	......	......	81 36	......	81·6	......	......	12·90	Middendorf.
R. Taimyr [illegible]	71 17	95 40	1843·5	21 51 E.	......	21·9 E.	82 16	......	82·3	......	......	......	Middendorf.
[illegible]	72 02	99 28	1843·5	13 55 E.	......	13·9 E.	81 40	......	81·7	......	......	12·69	Middendorf.
Sagatwere Village	73 22	127 08	1822·0	9 25 E.	3 35 E.	13·0 E.	......	......	......	......	......	......	Wrangel.
Island in the Lena	72 00	127 35	1822·0	7 00 E.	3 05 E.	10·1 E.	......	......	......	......	......	......	Wrangel.
Bulun Village	70 44	127 40	1822·0	4 30 E.	2 35 E.	7·1 E.	80 45	+42	81·5	......	......	......	Wrangel.
Village W. of the Lena	71 29	127 43	1822·0	6 00 E.	2 50 E.	8·8 E.	......	......	......	......	......	......	Wrangel.
Tschalbokoie	72 50	128 18	1822·0	8 10 E.	3 10 E.	11·3 E.	......	......	......	......	......	......	Wrangel.
Saki Island	72 31	129 26	1822·0	7 15 E.	3 05 E.	10·3 E.	81 28	+42	82·2	......	......	......	Wrangel.
Biawi (Mouth of)	72 04	130 06	1822·0	6 30 E.	2 53 E.	9·4 E.	81 11	+42	81·9	......	......	......	Wrangel.
Barkin	73 04	130 09	1822·0	......	......	......	81 48	+42	82·5	......	......	......	Anjou.
Cape Stalb	70 55	131 00	1822·0	5 00 E.	2 25 E.	7·4 E.	......	......	......	......	......	......	Wrangel.
Podkammen Guba	70 42	131 50	1822·0	......	......	......	79 49	+42	80·5	......	......	......	Anjou.
Stolb	72 02	136 16	1822·0	......	......	......	82 11	+42	82·9	......	......	......	Anjou.
Mouth of the Jana	70 55	136 31	1822·0	3 00 E.	2 05 E.	5·1 E.	79 54	+42	80·6	......	......	......	Wrangel.
Jarow Island	71 32	136 41	1822·0	......	......	......	80 11	+42	80·9	......	......	......	Wrangel.
Murasch Village	71 32	136 43	1822·0	5 20 E.	2 15 E.	7·6 E.	......	......	......	......	......	......	Wrangel.
Stolbowoi	74 02	136 45	1822·0	12 00 E.	3 00 E.	15·0 E.	......	......	......	......	......	......	Wrangel.
Kotelnoi Island (Winter Quarter)	74 50	138 37	1822·0	......	......	......	82 25	+42	83·1	......	......	......	Anjou.
Wankina Bay	72 00	139 59	1822·0	6 38 E.	2 12 E.	8·8 E.	80 49	+43	81·5	......	......	......	Wrangel.
Mouth of [illegible]	72 31	141 22	1822·0	8 07 E.	2 18 E.	10·4 E.	......	......	......	......	......	......	Wrangel.
[illegible] Island	73 54	142 30	1822·0	......	......	......	81 21	+44	82·1	......	......	......	Wrangel.
Mouth of Chroma R.	71 38	145 48	1822·0	8 42 E.	1 40 E.	10·4 E.	......	......	......	......	......	......	Wrangel.
Lake [illegible]	72 06	149 20	1822·0	11 03 E.	1 30 E.	12·6 E.	......	......	......	......	......	......	Wrangel.
Indigirka River	71 00	149 30	1821·5	9 58 E.	1 16 E.	11·2 E.	79 22	+47	80·2	......	......	......	Wrangel.
[illegible] River	70 50	153 43	1821·5	10 00 E.	1 06 E.	11·1 E.	......	......	......	......	......	......	Wrangel.
North [illegible]	71 01	158 10	1821·5	10 00 E.	1 03 E.	11·1 E.	......	......	......	......	......	......	Wrangel.
Mouth of [illegible] R.	70 43	159 18	1823·5	......	......	......	79 00	+45	79·8	......	......	......	Wrangel.
Fourth Bear Island	70 47	161 40	1821·5	14 00 E.	0 54 E.	14·9 E.	......	......	......	......	......	......	Wrangel.
S.E. Point of ditto	70 37	162 21	1821·5	14 06 E.	0 50 E.	14·9 E.	79 49	+47	80·6	......	......	......	Wrangel.
Station	70 13	162 40	1821·5	......	......	......	78 15	+47	79·0	......	......	......	Wrangel.
On ice	71 37	163 23	1821·5	......	......	......	80 17	+47	81·1	......	......	......	Wrangel.
On ice	70 41	165 22	1821·5	14 51 E.	0 47 E.	15·6 E.	......	......	......	......	......	......	Wrangel.
On ice	70 39	165 42	1822·5	14 30 E.	0 47 E.	15·3 E.	......	......	......	......	......	......	Wrangel.
On ice	71 13	166 04	1822·5	15 00 E.	0 54 E.	15·9 E.	......	......	......	......	......	......	Wrangel.
On ice	71 34	166 41	1822·5	17 00 E.	0 59 E.	18·0 E.	......	......	......	......	......	......	Wrangel.
On ice	71 52	166 51	1822·5	18 45 E.	1 00 E.	19·8 E.	......	......	......	......	......	......	Wrangel.
On ice	71 50	167 11	1822·5	18 45 E.	1 00 E.	19·8 E.	......	......	......	......	......	......	Wrangel.
On ice	71 18	167 54	1822·5	18 00 E.	0 54 E.	18·9 E.	......	......	......	......	......	......	Wrangel.
Ice, distant from shore	70 53	170 00	1822·5	18 40 E.	0 42 E.	19·4 E.	81 09	+46	81·9	......	......	......	Wrangel.
Station	70 53	170 31	1822·5	18 48 E.	0 42 E.	19·5 E.	79 58	+46	80·7	......	......	......	Wrangel.
Cape Schelagskoi	70 03	171 03	1823·5	18 03 E.	0 30 E.	18·6 E.	......	......	......	......	......	......	Wrangel.
Kosmin Rock	70 01	171 55	1823·5	18 00 E.	0 28 E.	18·5 E.	......	......	......	......	......	......	Wrangel.
Station	70 20	174 13	1823·5	21 30 E.	0 28 E.	22·0 E.	......	......	......	......	......	......	Wrangel.
At sea	70 54	184 20	1849·5	29 44 E.	......	29·7 E.	......	......	......	......	......	......	Kellett.
At sea	70 27	185 44	1849·5	27 56 E.	......	27·9 E.	......	......	......	......	......	......	Kellett.
At sea	70 40	186 02	1849·5	28 13 E.	......	28·2 E.	......	......	......	......	......	......	Kellett.
At sea	70 18	186 46	1849·5	30 14 E.	......	30·2 E.	......	......	......	......	......	......	Kellett.
At sea	70 44	188 00	1849·5	29 07 E.	......	29·1 E.	......	......	......	......	......	......	Kellett.
At sea	70 59	189 33	1849·5	32 57 E.	......	33·0 E.	......	......	......	......	......	......	Kellett.
At sea	70 00	190 54	1849·5	29 34 E.	......	29·6 E.	......	......	......	......	......	......	Kellett.
At sea	70 06	192 27	1850·5	32 16 E.	......	32·3 E.	......	......	......	......	......	......	Kellett.

ZONE VII.—Lat. 70° to 75° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.	Inclination. Observed.	Inclination. Cor. to Epoch 1842·5.	Inclination. Corrected.	Force in British units. Observed.	Force in British units. Cor. to Epoch 1842·5	Force in British units. Corrected.	Observers.
	° ′	° ′		° ′		°	° ′		°				
At sea	72 49	195 33	1849·5	40 44 E.	......	40·7 E.	......	......	......	......	......	......	Kellett.
At sea	72 50	196 00	1850·5	......	......	......	82 15	......	82·3	......	......	......	Collinson.
At sea	70 17	196 08	1849·5	34 35 E.	......	34·6 E.	......	......	......	......	......	......	Kellett.
At sea	72 05	196 19	1849·5	35 19 E.	......	35·3 E.	......	......	......	......	......	......	Kellett.
At sea	70 21	196 33	1850·5	32 39 E.	......	32·7 E.	......	......	......	......	......	......	Collinson.
At sea	71 10	196 36	1849·5	36 13 E.	......	36·2 E.	......	......	......	......	......	......	Kellett.
At sea	71 02	196 58	1849·5	35 57 E.	......	36·0 E.	......	......	......	......	......	......	Kellett.
At sea	71 37	197 09	1849·5	35 48 E.	......	35·8 E.	......	......	......	......	......	......	Kellett.
At sea	70 32	197 16	1849·5	33 35 E.	......	33·6 E.	......	......	......	......	......	......	Kellett.
At sea	70 28	197 40	1850·5	......	......	......	80 58	......	81·0	......	......	......	Collinson.
At sea	71 02	197 49	1849·5	37 19 E.	......	37·3 E.	......	......	......	......	......	......	Kellett.
At sea	71 40	198 16	1849·5	38 36 E.	......	38·6 E.	......	......	......	......	......	......	Kellett.
At sea	70 30	198 39	1849·5	34 57 E.	......	35·0 E.	......	......	......	......	......	......	Kellett.
At sea	70 37	198 44	1849·5	36 06 E.	......	36·1 E.	......	......	......	......	......	......	Kellett.
At sea	70 31	199 20	1826·5	......	......	......	81 03	......	81·1	......	......	......	Beechey.
Wainwright Inlet	70 37	199 57	1849·5	36 41 E.	......	36·7 E.	......	......	......	......	......	......	Kellett.
At sea	70 58	200 06	1849·5	36 42 E.	......	36·7 E.	......	......	......	......	......	......	Kellett.
At sea	72 08	200 16	1850·5	41 09 E.	......	41·2 E.	......	......	......	......	......	......	Collinson.
At sea	71 24	200 53	1851·5	38 20 E.	......	38·3 E.	......	......	......	......	......	......	Collinson.
At sea	72 21	200 55	1850·5	......	......	......	83 08	......	83·1	......	......	......	Collinson.
At sea	71 17	200 59	1851·5	40 51 E.	......	40·9 E.	......	......	......	......	......	......	Collinson.
Point Barrow	71 29	204 00	1854·0	41 00 E.	......	41·0 E.	81 36	......	81·6	......	......	......	Maguire.
On ice	71 27	204 46	1851·5	......	......	......	82 29	......	82·5	......	......	......	Collinson.
On ice	71 29	205 00	1851·5	40 00 E.	......	40·0 E.	......	......	......	......	......	......	Collinson.
Boat Extreme	71 02	205 37	1837·5	42 36 E.	......	42·6 E.	......	......	......	......	......	......	Simpson.
At sea	71 33	205 45	1851·5	......	......	......	81 34	......	84·6	......	......	......	Collinson.
At sea	71 30	207 00	1851·5	45 43 E.	......	45·7 E.	......	......	......	......	......	......	Collinson.
On ice	71 31	207 25	1851·5	45 17 E.	......	45·3 E.	......	......	......	......	......	......	Collinson.
Point Comfort	70 43	207 46	1837·5	43 08 E.	......	43·1 E.	......	......	......	......	......	......	Simpson.
At sea	70 34	210 28	1851·5	43 47 E.	......	43·8 E.	......	......	......	......	......	......	Collinson.
On ice (4 observations)	70 31	211 26	1850·5	44 37 E.	......	44·6 E.	......	......	......	......	......	......	M'Clure.
Foggy Island	70 16	212 22	1825·5	43 15 E.	......	43·3 E.	82 26	......	82·4	......	......	......	Franklin.
Point Anxiety	70 10	212 30	1837·5	45 00 E.	......	45·0 E.	......	......	......	......	......	......	Simpson.
On ice	71 26	212 34	1851·5	......	......	......	83 05	......	83·1	......	......	......	Collinson.
At sea	70 22	213 20	1851·5	38 00 E.	......	38·0 E.	......	......	......	......	......	......	Collinson.
On ice	70 09	216 10	1851·5	......	......	......	82 58	......	83·0	......	......	......	Collinson.
At sea	70 06	216 45	1851·5	42 38 E.	......	42·6 E.	......	......	......	......	......	......	Collinson.
At sea	70 20	218 45	1851·5	42 13 E.	......	42·2 E.	......	......	......	......	......	......	Collinson.
At sea	70 17	219 55	1851·5	......	......	......	83 37	......	83·6	......	......	......	Collinson.
At sea	70 05	220 13	1851·5	48 11 E.	......	48·2 E.	......	......	......	......	......	......	Collinson.
At sea	70 01	226 36	1851·5	48 41 E.	......	48·7 E.	......	......	......	......	......	......	Collinson.
At sea	70 20	228 58	1851·5	53 31 E.	......	53·5 E.	......	......	......	......	......	......	Collinson.
At sea	70 04	230 18	1851·5	......	......	......	84 30	......	84·5	......	......	......	Collinson.
At sea	70 50	232 19	1851·5	58 05 E.	......	58·1 E.	......	......	......	......	......	......	Collinson.
At sea	72 34	234 46	1851·5	76 05 E.	......	76·1 E.	......	......	......	......	......	......	Collinson.
On shore	71 06	237 00	1850·5	80 14 E.	......	80·2 E.	......	......	......	......	......	......	M'Clure.
On the shore ice	74 27	237 29	1851·5	86 24 E.	......	86·4 E.	......	......	......	......	......	......	M'Clure.
At sea	70 56	239 00	1851·5	......	......	......	85 09	......	85·2	......	......	......	Collinson.
At sea	71 25	239 40	1851·5	68 55 E.	......	68·9 E.	......	......	......	......	......	......	Collinson.
At sea	71 16	240 43	1851·5	......	......	......	86 33	......	86·6	......	......	......	Collinson.
At sea	71 53	241 05	1851·5	73 34 E.	......	73·6 E.	......	......	......	......	......	......	Collinson.
On ice	74 06	241 45	1851·5	96 14 E.	......	96·2 E.	......	......	......	......	......	......	M'Clure.
Winter Cove	71 35	242 22	1852·5	82 20 E.	......	82·3 E.	87 47	......	87·8	......	......	......	Collinson.
On ice	72 47	242 26	1851·5	83 04 E.	......	83·1 E.	......	......	......	......	......	......	M'Clure.
At sea	73 20	243 35	1851·5	......	......	......	86 52	......	87·9	......	......	......	Collinson.
On ice	73 05	243 54	1851·5	89 16 E.	......	89·3 E.	......	......	......	......	......	......	M'Clure.
On ice	73 12	244 17	1851·5	93 12 E.	......	93·2 E.	......	......	......	......	......	......	M'Clure.
On shore	74 26	246 12	1820·5	106 07 E.	......	106·1 E.	......	......	......	......	......	......	Sabine.
On shore	74 24	247 07	1820·5	110 56 E.	......	110·9 E.	......	......	......	......	......	......	Sabine.
On shore	74 25	247 19	1820·5	111 19 E.	......	111·3 E.	......	......	......	......	......	......	Sabine.
On shore	74 27	247 49	1820·5	114 35 E.	......	114·6 E.	......	......	......	......	......	......	Sabine.

ZONE VII.—Lat. 70° to 75° N. (continued).

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]							[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]				[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]				[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]							
On ice	74 55	255 48	1819·5	......	......	......	88 29	......	88·5	......	......	......	Sabine.
On ice	74 30	257 50	1857·5	179 40?	......	179·7 ?	......	......	......	......	......	......	McDougall.
[illegible]	73 01	258 17	1851·5	168 40 E.	......	168·7 E.	......	......	......	......	......	......	Ommanney.
[illegible]	73 00	258 21	1851·5	169 07 E.	......	169·1 E.	......	......	......	......	......	......	Ommanney.
[illegible]	73 03	258 52	1851·5	170 57 E.	......	171·0 E.	......	......	......	......	......	......	Ommanney.
							......	......	......	......	......	......	Ommanney.
[illegible] (mean of 3 obs.)...	70 14	258 53	1851·5	......	......	......	89 30	......	89·5	......	......	......	Collinson.
Prince of Wales Land	73 37	258 55	1853·5	172 00 E.	......	172·0 E.	......	......	......	......	......	......	Ommanney.
On ice	70 08	258 58	1853·5	......	......	......	89 26	......	89·4	......	......	......	Collinson.
Prince of Wales Land	73 06	259 08	1851·5	171 38	......	171·6	......	......	......	......	......	......	Ommanney.
On shore	70 22	259 15	1853·5	......	......	......	89 20	......	89·3	......	......	......	Collinson.
Prince of Wales Land	74 01	259 53	1851·5	166 20 W.	......	166·3 W.	......	......	......	......	......	......	Ommanney.
Resting Place	73 55	260 35	1851·5	163 35 W.	......	163·6 W.	88 16	......	88·3	......	......	......	Ommanney.
Prince of Wales Land	73 59	260 51	1851·5	159 02 W.	......	159·0 W.	......	......	......	......	......	......	Ommanney.
Prince of Wales Land	74 03	261 35	1851·5	166 09 W.	......	166·1 W.	......	......	......	......	......	......	Ommanney.
Cape Walker	74 06	262 22	1851·5	157 33 W.	......	157·6 W.	88 11	......	88·2	......	......	......	Ommanney.
On land	70 05	263 14	1831·5	......	......	......	89 59	......	90·0	......	......	......	Ross.
On ice	70 11	263 15	1859·5	......	......	......	89 52	......	89·9	......	......	......	McClintock.
[illegible]	70 07	263 25	1859·5	......	......	......	89 49	......	89·8	......	......	......	McClintock.
[illegible]	71 08	263 30	1859·0	......	......	......	89 13	......	89·2	......	......	......	McClintock.
[illegible]	70 33	263 30	1859·5	......	......	......	89 13	......	89·2	......	......	......	McClintock.
[illegible]	70 49	263 30	1859·5	......	......	......	89 16	......	89·3	......	......	......	McClintock.
Prince of Wales Land	71 25	263 57	1851·5	153 00 W.	......	153·0 W.	......	......	......	......	......	......	Ommanney.
Prince of Wales Land	71 25	264 00	1859·5	......	......	......	89 01	......	89·0	......	......	......	McClintock.
On the beach	73 22	264 18	1849·5	......	......	......	88 27	......	88·5	......	......	......	Ross.
On ice near Griffith's Island	74 37	264 20	1850·5	......	......	......	87 53	......	87·9	......	......	......	R. C. Allen.
On the beach	73 12	264 29	1849·5	......	......	......	88 31	......	88·5	......	......	......	Ross.
On ice, Winter Station	74 36	264 42	1851·5	......	......	......	87 53	......	87·9	12·39	......	12·39	Ommanney.
On the beach	74 01	264 49	1849·5	......	......	......	88 14	......	88·2	......	......	......	Ross.
Griffith's Island	74 35	264 50	1851·5	......	......	......	87 58	......	88·0	......	......	......	Ommanney and Allen.
Cape Bird	71 59	264 52	1858·5	138 00 W.	......	138·0 W.	88 12	......	88·2	......	......	......	McClintock.
Port Kennedy	72 01	265 40	1858·5	135 47 W.	......	135·8 W.	88 27	......	88·5	......	......	......	McClintock.
Depôt Bay	72 01	265 49	1858·5	......	......	......	88 23	......	88·4	......	......	......	McClintock.
Near Barlow's Inlet, on ice	74 43	266 41	1850·5	141 17 W.	......	141·3 W.	87 34	......	87·6	12·33	......	12·33	Ommanney.
On the beach	74 08	267 09	1849·5	......	......	......	87 36	......	87·6	......	......	......	Ross.
On the beach	74 00	267 57	1849·5	......	......	......	87 44	......	87·7	......	......	......	Ross.
Sheriff's Bay	70 01	268 06	1831·0	96 12 W.	......	96·2 W.	89 00	......	89·0	......	......	......	Ross.
On land	72 47	268 09	1825·5	129 24 W.	......	129·4 W.	88 19	......	88·3	......	......	......	Parry.
Land ice, Beechey Id.	74 40	268 12	1850·5	......	......	......	87 29	......	87·5	......	......	......	R. C. Allen.
Near Cape Riley	74 40	268 13	1819·5	129 00 W.	......	129·0 W.	......	......	......	......	......	......	Sabine.
Cape Riley	74 42	268 17	1853·5	......	......	......	......	......	......	12·72	......	12·72	Bellot.
Victory Harbour	70 09	268 29	1832·0	101 32 W.	......	101·5 W.	88 55	......	88·9	......	......	......	Ross.
On land	73 06	268 40	1825·0	128 24 W.	......	128·4 W.	88 02	......	88·0	......	......	......	Parry.
On the beach	74 02	268 53	1849·5	......	......	......	87 36	......	87·6	......	......	......	Ross.
Barrow's Strait	74 35	268 55	1850·5	135 21 W.	......	135·4 W.	......	......	......	......	......	......	Ommanney.
On ice	73 23	269 07	1825·5	125 36 W.	......	125·6 W.	......	......	......	......	......	......	Parry.
Port Leopold	73 52	269 43	1849·0	129 13 W.	......	129·2 W.	87 38	......	87·6	13·05	......	13·05	Robinson and Brown.
E. shore, Regent's Inlet	72 45	270 19	1819·5	118 16 W.	......	118·3 W.	88 27	......	88·5	12·46	......	12·46	Sabine.
On ice	72 57	270 30	1819·5	......	......	......	88 25	......	88·4	......	......	......	Sabine.
On shore	73 12	270 58	1819·5	114 17 W.	......	114·3 W.	......	......	......	......	......	......	Parry and Sabine.

3 M 2

ZONE VII.—Lat. 70° to 75° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.	Inclination. Observed.	Inclination. Cor. to Epoch 1842·5.	Inclination. Corrected.	Force in British units. Observed.	Force. Cor. to Epoch 1842·5.	Force. Corrected.	Observers.
	° ′	° ′		° ′		°	° ′		°				
Neill's Harbour	73 09	270 59	1825·0	118 49 w.	......	118·8 w.	88 08	......	88·1	......	......	......	Parry.
Port Bowen	73 14	271 05	1825·0	124 00 w.	......	124·0 w.	88 01	......	88·0	13·26	......	13·26	Parry and Foster.
E. Shore, Regent's Inlet	73 33	271 42	1819·5	115 37 w.	......	115·6 w.	87 36	......	87·6	......	......	......	Parry and Sabine.
Dundas Harbour, on ice	74 35	277 45	1853·5	......	......	......	86 26	......	86·4	12·91	......	12·91	Bellot.
Cape Warrender	74 28	278 09	1824·5	104 48 w.	......	104·8 w.	......	......	......	......	......	......	Parry.
Barrow's Strait	74 22	278 58	1857·5	110 00 w.	......	110·0 w.	......	......	......	......	......	......	McDougall.
On ice	74 26	279 55	1819·5	106 58 w.	......	107·0 w.	......	......	......	......	......	......	Sabine.
At sea	74 47	280 35	1850·5	109 15 w.	......	109·3 w.	......	......	......	......	......	......	Ommanney.
Possession Bay	73 31	282 38	1819·5	108 47 w.	......	108·8 w.	86 04	......	86·1	12·23	......	12·23	Parry and Sabine.
Off Cape Graham Moore	72 54	284 30	1858·5	103 31 w.	......	103·5 w.	......	......	......	......	......	......	McClintock.
On shore	71 16	288 43	1820·5	91 28 w.	......	91·5 w.	......	......	......	......	......	......	Sabine.
On shore	70 22	291 23	1820·5	80 59 w.	......	81·0 w.	......	......	......	......	......	......	Sabine.
On ice	70 35	293 05	1818·5	86 53 w.	......	86·9 w.	84 39	......	84·7	12·41	......	12·41	Sabine.
Baffin's Bay	74 52	294 15	1857·5	91 58 w.	......	92·0 w.	......	......	......	......	......	......	McClintock.
On ice	72 34	297 52	1824·5	83 26 w.	......	83·4 w.	......	......	......	......	......	......	Parry.
On ice	72 28	298 33	1824·5	83 00 w.	......	83·0 w.	......	......	......	......	......	......	Parry.
On ice, Davis Strait	70 56	299 08	1824·5	78 24 w.	......	78·4 w.	84 09	......	84·2	......	......	......	Parry.
On ice	71 02	299 24	1824·5	77 42 w.	......	77·7 w.	......	......	......	......	......	......	Parry.
On ice	73 03	299 49	1819·5	82 05 w.	......	82·1 w.	......	......	......	......	......	......	Sabine.
Ice in Baffin's Bay	72 00	300 00	1819·5	80 55 w.	......	80·9 w.	84 15	......	84·3	......	......	......	Sabine.
On ice	71 16	300 38	1824·5	78 50 w.	......	78·8 w.	......	......	......	......	......	......	Parry.
On ice	74 58	300 44	1818·5	84 33 w.	......	84·6 w.	......	......	......	......	......	......	Sabine.
On ice	70 29	300 48	1819·5	74 39 w.	......	74·7 w.	......	......	......	......	......	......	Sabine.
On ice	74 35	301 02	1848·5	......	......	......	83 51	......	83·9	......	......	......	Brown.
On ice	74 35	301 13	1848·5	......	......	......	84 00	......	84·0	......	......	......	Brown.
			1850·5	......	......	......	83 49	......	83·8 } 83·8	......	......	......	R. C. Allen.
			1850·5	......	......	......	83 35	......	83·6	12·00	......	12·00	Ommanney.
On ice	74 14	301 30	1857·5	87 00 w.	......	87·0 w.	......	......	......	......	......	......	McDougall.
At sea (3 observations)	74 20	301 54	1848·5	......	......	......	85 01	......	85·1	......	......	......	Robinson.
At sea	71 30	301 55	1818·5	......	......	......	84 27	......	84·5	......	......	......	Robinson.
Baffin's Three Islands	74 01	302 08	1818·5	80 44 w.	......	} 80·7 w.	84 09	......	84·2 } 84·0	......	......	......	Sabine.
			1850·5	......	......		83 47	......	83·8	......	......	......	R. C. Allen.
Islet in Hingston Bay	73 50	302 08	1850·5	......	......	......	83 27	......	83·5	......	......	......	Ommanney.
At sea (2 observations)	71 50	302 27	1848·5	......	......	......	84 59	......	85·0	......	......	......	Robinson.
On ice	73 22	302 28	1818·5	80 01 w.	......	80·0 w.	......	......	......	......	......	......	Sabine.
On ice	73 37	302 53	1848·5	......	......	......	83 16	......	83·3	......	......	......	Brown.
On ice	73 48	303 08	1850·5	......	......	......	83 37	......	83·6	......	......	......	R. C. Allen.
On ice	72 44	303 11	1818·5	78 55 w.	......	78·9 w.	......	......	......	......	......	......	Sabine.
At sea (2 observations)	73 32	303 17	1848·5	......	......	......	82 43	......	82·7	......	......	......	Robinson.
On ice	73 10	303 36	1850·5	......	......	......	83 22	......	83·4	12·21	......	12·21	Ommanney.
Upernavik	72 47	303 57	1848·5	......	......	......	83 24	......	83·4 } 83·6	......	......	......	Robinson.
			1853·5	......	......	......	83 42	......	83·7	......	......	......	Kane.
			1861·5	72 12 w.	......	72·2 w.	......	......	......	12·38	......	12·38	Hayes & Radcliff
Proven	72 23	304 30	1853·5	......	......	......	82 57	......	82·9	12·84	......	12·84	Kane.
			1860·5	83 24 w.	......	83·4 w.	......	......	......	......	......	......	Sonntag.
Hare Island	70 26	305 08	1818·5	71 58 w.	......	72·0 w.	82 49	......	82·8	12·12	......	12·12	Sabine.
On ice	71 02	305 47	1818·5	75 30 w.	......	75·5 w.	......	......	......	......	......	......	Sabine.
Forster Bay	72 40	338 00	1822·5	45 00 w.	......	45·0 w.	......	......	......	......	......	......	Scoresby.
Scoresby's Straits	70 25	338 18	1822·5	43 24 w.	......	43·4 w.	......	......	......	......	......	......	Scoresby.
At sea	71 50	339 17	1822·5	43 24 w.	......	43·4 w.	......	......	......	......	......	......	Scoresby.
Sabine Island	74 32	341 10	1823·5	......	......	} 45·1 w.	80 11	......	} 80·0	11·54	......	11·54	Sabine.
			1870·5	45 08 w.	......		79 48	......		......	......	......	Copeland.
At sea	73 17	342 20	1822·5	43 15 w.	......	43·3 w.	......	......	......	......	......	......	Scoresby.
Gael Hamke's Bay	73 54	343 20	1822·5	42 08 w.	......	42·1 w.	......	......	......	......	......	......	Scoresby.
On ice	73 21	343 55	1868·5	41 25 w.	......	41·4 w.	......	......	......	......	......	......	Copeland.

ZONE VIII.—LATITUDE 75° TO 90° N.

Authorities.

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Franklin .... Fisher	Beechey, Voyage in 1818 (London, 1843).
Sabine	Pendulum and other Experiments (London, 1825); and Parry's Voyage, 1819 and 1820.
Parry and Foster....	Parry's Voyage, 1827.
Gaimard	Voyages en Scandinavie &c., 1838–1840.
Parry & James Ross..	Parry's Voyage, 1827.
Lütke	MSS. in Magnetic Office, received from Admiral Count Lütke.
Pakhtussoff	In Belavenetz, 1871 (in the Russian Language); and MSS. in the Magnetic Office, received from Admiral Count Lütke.
Johannesen	Petermann, Mittheilungen, 1871.
Allen	MSS. in Magnetic Office, received from Mr. R. C. Allen, R.N., Master of the 'Resolute.'
Belcher............	MSS. received from the British Hydrographic Office.
Kane .... Hayes .... Sonntag .... Radcliff .... McCormick	Smithsonian Contributions, vols. x. and xv.
Ommanney	MSS. in Magnetic Office, communicated by Admiral Ommanney.
McClintock	MSS. in Magnetic Office, communicated by Admiral Sir Leopold McClintock.
Bellot	MSS. in Magnetic Office, communicated by Admiral Inglefield.
Robinson .... Brown	MSS. in Magnetic Office, communicated by Lieut. Robinson, R.N.

ZONE VIII.—Lat. 75° to 85° N.

[illegible]	[illegible] N.	[illegible] E.	[illegible]	Declination.			Inclination.				Force in British units.			Observers.
				[illegible]	[illegible] 1842·5.	[illegible]	[illegible]	[illegible] 1842·5.	[illegible]		Observed.	Cor. to Epoch 1842·5.	Corrected.	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		......	......	......	Lemström.
[illegible]	79 50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					......	......	......	Lemström.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		......	......	......	Lemström.
[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]		11·67	......	11·67	Bock and Meyer.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		11·53	......	11·53	Lemström.
Danes Island	79 40	11 06	1818·5	24 30 w.	2 48 E.	21·7 w.	81 03	−24	80·7		11·66	......	11·66	Fisher.
South Gat	79 40	11 07	1868·5	......	......	......	80 06	+26	80·5		......	......	......	Lemström.
Amsterdam Island ...	79 44	11 10	1868·5	19 31 w.	3 02 w.	22·6 w.	80 01	+26	80·5		......	......	......	Lemström.
Magdalena Bay	79 34	11 30	1818·5	24 30 w.	2 48 E.	21·7 w.	81 02	−24	80·6		......	......	......	Fisher.
Danes Island	79 42	11 32	1861·5	......	......	......	80 27	+19	80·8		......	......	......	Chydenius.
			1773·5	......	......	......	82 00	−69	80·9		......	......	......	Phipps.
Norway Island	79 50	11 41	1823·5	25 12 w.	2 13 E.	23·0 w.	81 11	−19	80·9	° 80·9	11·70	......	11·70	Sabine.
			1861·5	......	......	......	80 35	+19	80·9		......	......	......	Chydenius.
King's Bay	78 57	11 59	1868·5	18 32 w.	3 02 w.	21·6 w.	80 00	+26	80·4		11·51	......	11·51	Lemström.
On ice	79 50	12 00	1818·5	24 12 w.	2 48 E.	21·4 w.	81 28	−24	81·1		......	......	......	Fisher.
On ice	79 57	13 18	1827·5	22 42 w.	1 45 E.	21·0 w.	......	......	......		......	......	......	Parry and Foster.
Moffen Island	80 01	14 07	1861·5	......	......	......	80 23	+19	80·7		......	......	......	Chydenius.
Green Harbour	78 01	14 13	1868·5	16 14 w.	3 02 w.	19·3 w.	80 13	+26	80·7		11·42	......	11·42	Lemström.
On ice	79 53	14 34	1827·5	24 12 w.	1 45 E.	22·5 w.	......	......	......		......	......	......	Parry.
Bell Sound	77 30	14 34	1840·0	20 36 w.	0 28 E.	20·1 w.	79 38	− 4	79·6		11·66	......	11·66	Bock and Meyer.
South Cape	76 30	14 38	1827·5	......	......	......	79 51	−15	79·6		11·51	......	11·51	Keilhau.
On ice	79 49	15 25	1827·5	18 51 w.	1 45 E.	17·1 w.	......	......	......		......	......	......	Parry.
On ice	79 50	15 36	1827·5	18 11 w.	1 45 E.	16·4 w.	......	......	......		......	......	......	Parry.
Advent Bay	78 15	15 58	1868·5	14 42 w.	3 02 w.	17·7 w.	80 07	+26	80·6		11·16	......	11·16	Lemström.
Bear Island	75 [illegible]	16 00	1827·5	......	......	......	78 54	−15	78·7		11·41	......	11·41	Keilhau.
On ice	81 42	16 35	1868·5	......	......	......	80 59	+26	81·4		......	......	......	Lemström.
Treurenberg Bay	79 57	16 49	1861·5	......	......	......	80 34	+19	80·9		......	......	......	Chydenius.
Hecla Cove	79 55	16 49	1827·5	18 46 w.	1 45 E.	17·0 w.	80 55	−15	80·7	80·8	......	......	......	Parry and Foster.
			1861·5	......	......	......	80 33	+19	80·9		......	......	......	Chydenius.
Verlegen Hook	80 02	16 54	1861·5	......	......	......	80 20	+19	80·7		......	......	......	Chydenius.
On ice	82 14	17 18	1827·5	22 23 w.	1 45 E.	20·6 w.	......	......	......		......	......	......	Parry and Ross.
Waigats Straits	79 55	17 29	1827·5	17 49 w.	1 45 E.	16·1 w.	......	......	......		......	......	......	Foster.
Loom Bay	79 26	17 45	1861·5	......	......	......	80 15	+19	80·6		......	......	......	Chydenius.
On ice	82 06	17 46	1827·5	20 47 w.	1 45 E.	19·0 w.	......	......	......		......	......	......	Parry and Ross.
Bear Bay	79 37	17 54	1827·5	17 20 w.	1 45 E.	15·6 w.	......	......	......		......	......	......	Foster.
On ice	81 58	17 56	1827·5	20 25 w.	1 45 E.	18·7 w.	......	......	......		......	......	......	Parry and Ross.
Depôt Island	80 00	17 57	1861·5	......	......	......	80 34	+19	80·9		......	......	......	Chydenius.
Whales Head	77 20	18 00	1827·5	......	......	......	80 00	−15	79·8		11·73	......	11·73	Keilhau.
Loom Bay	79 38	18 07	1868·5	......	......	......	81 08	+26	81·6		......	......	......	Lemström.
Low Island	80 17	18 12	1827·5	......	......	......	81 23	−15	81·4		......	......	......	Parry.
Low Island	80 20	18 23	1861·5	......	......	......	80 40	+19	81·0		......	......	......	Chydenius.
Foster's Island	79 35	19 17	1827·5	15 40 w.	2 15 E.	13·4 w.	......	......	......		......	......	......	Foster.
On ice	82 40	19 25	1827·5	18 10 w.	2 15 E.	15·9 w.	82 22	−15	82·1		......	......	......	Parry and Ross.
Walden Island	80 36	19 51	1827·5	17 42 w.	2 15 E.	15·5 w.	81 24	−15	81·2		......	......	......	Parry and Foster.
On ice	82 39	19 52	1827·5	19 05 w.	2 15 E.	16·8 w.	82 22	−15	82·1		......	......	......	Ross.
North Cape	80 31	20 22	1868·5	......	......	......	81 20	+26	81·8		......	......	......	Lemström.
On ice	82 27	20 32	1827·5	17 28 w.	2 30 E.	15·0 w.	......	......	......		......	......	......	Parry and Ross.
Hinlopen Strait	79 03	21 02	1868·5	10 26 w.	3 54 w.	14·3 w.	......	......	......		......	......	......	North German Exploration, 1868
On ice	81 22	21 33	1827·5	15 31 w.	2 30 E.	13·0 w.	......	......	......		......	......	......	Parry and Ross.
On ice	82 14	22 04	1827·5	15 06 w.	2 30 E.	12·6 w.	82 16	−15	82·0		......	......	......	Parry and Ross.
On ice	82 03	23 17	1827·5	13 41 w.	2 30 E.	11·2 w.	......	......	......		......	......	......	Parry and Ross.
On ice	81 45	24 28	1827·5	13 16 w.	2 30 E.	10·8 w.	82 05	−15	81·8		......	......	......	Parry and Ross.
At sea	75 50	42 30	1824·5	3 48 E.	1 48 E.	5·6 E.	......	......	......		......	......	......	Lütke.
At sea	76 05	44 00	1824·5	4 16 E.	1 48 E.	6·1 E.	......	......	......		......	......	......	Lütke.
At sea	75 15	46 50	1824·5	7 28 E.	1 48 E.	9·3 E.	......	......	......		......	......	......	Lütke.
At sea	75 49	57 58	1822·5	15 00 E.	2 00 E.	17·0 E.	......	......	......		......	......	......	Lütke.
At sea	76 28	58 50	1823·5	14 00 E.	1 54 E.	15·9 E.	......	......	......		......	......	......	Lütke.
Berg Island	75 56	58 52	1835·5	15 00 E.	0 42 E.	15·7 E.	......	......	......		......	......	......	Pakhtussoff.
Hare Island	75 54	58 56	1835·5	15 00 E.	0 42 E.	15·7 E.	81 06	− 5	81·0		......	......	......	Pakhtussoff.
Nova Zembla	75 32	59 30	1822·5	12 34 E.	2 00 E.	14·6 E.	......	......	......		......	......	......	Lütke.
Nova Zembla	76 48	79 00	1870·5	30 30 E.	2 48 w.	27·7 E.	......	......	......		......	......	......	Johannesen.

ZONE VIII.—Lat. 75 to 85° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Declination. Correction to Epoch 1842·5.	Declination. Corrected.	Inclination. Observed.	Inclination. Cor. to Epoch 1842·5.	Inclination. Corrected.	Force in British units. Observed.	Force in British units. Cor. to Epoch 1842·5.	Force in British units. Corrected.	Observers.
	° ′	° ′		° ′	° ′	°	° ′	′	°				
Bolkow Island	75 52	136 50	1822·5	......	......	......	82 58	+40	83·6	......	......	......	Wrangel.
On ice	76 36	137 26	1822·5	16 00 E.	3 00 E.	19·0 E.	83 08	+40	83·8	......	......	......	Anjou.
On ice	76 02	138 53	1822·5	14 43 E.	3 00 E.	17·7 E.	82 51	+40	83·5	......	......	......	Anjou.
Cape Nerpowoi	75 47	143 33	1822·5	......	......	......	82 26	+40	83·1	......	......	......	Wrangel.
River Mutnaia	75 12	149 53	1822·5	......	......	......	82 22	+40	83·0	......	......	......	Anjou.
Mouth of the Mutnaia	75 04	150 34	1822·5	15 15 E.	2 20 E.	17·6 E.	......	......	......	......	......	......	Wrangel.
Cape K[illegible]	75 06	150 53	1822·5	15 15 E.	2 20 E.	17·6 E.	......	......	......	......	......	......	Wrangel.
Melville Island	75 05	248 03	1820·5	123 48 E.	......	123·8 E.	......	......	......	......	......	......	Sabine.
Melville Island	75 13	248 10	1820·5	125 15 E.	......	125·3 E.	......	......	......	......	......	......	Sabine.
Melville Island	75 03	248 23	1820·5	126 02 E.	......	126·0 E.	......	......	......	......	......	......	Sabine.
Melville Island	75 21	249 27	1820·5	131 47 E.	......	131·8 E.	......	......	......	......	......	......	Sabine.
[illegible]	75 12	254 02	1854·5	158 00 E.	......	158·0 E.	......	......	......	......	......	......	Kellett.
[illegible]	75 03	254 06	1819·5	158 04 E.	......	158·1 E.	......	......	......	......	......	......	Sabine.
[illegible]	75 10	256 16	1819·5	165 50 E.	......	165·8 E.	88 26	− 9	88·3	12·35	......	12·35	Sabine.
Harbour Hill, on shore	76 51	263 00	1852·5	150 47 W.	......	150·8 W.	......	......	......	......	......	......	Belcher.
[illegible]	76 57	263 05	1852·5	155 23 W.	......	155·4 W.	......	......	......	......	......	......	Belcher.
[illegible]	[illegible] 43	263 15	1852·5	146 12 W.	......	146·2 W.	......	......	......	......	......	......	Belcher.
[illegible]	76 28	264 00	1853·5	152 00 W.	......	152·0 W.	......	......	......	......	......	......	Belcher.
[illegible]	76 27	264 05	1853·5	152 27 W.	......	152·5 W.	......	......	......	......	......	......	Belcher.
[illegible]	77 16	264 10	1852·5	156 42 W.	......	156·7 W.	......	......	......	......	......	......	Belcher.
Depôt Station	77 00	264 57	1853·5	146 42 W.	......	146·7 W.	......	......	......	......	......	......	Belcher.
North Cornwall	77 34	265 03	1852·5	154 20 W.	......	154·3 W.	......	......	......	......	......	......	Belcher.
Floe, East of Margaret Island	76 04	265 15	1853·5	153 17 W.	......	153·3 W.	......	......	......	......	......	......	Belcher.
Refuge Bay	76 16	265 15	1853·5	151 38 W.	......	151·6 W.	......	......	......	......	......	......	Belcher.
Off Baillie Hamilton Island	76 01	265 20	1853·5	149 49 W.	......	149·8 W.	......	......	......	......	......	......	Belcher.
Gravel Island and Bank	76 56	265 32	1853·5	154 15 W.	......	154·3 W.	......	......	......	......	......	......	Belcher.
Princess Royal Island	76 58	265 40	1853·5	147 43 W.	......	147·7 W.	......	......	......	......	......	......	Belcher.
Mount Parker	76 52	266 23	1853·5	149 28 W.	......	149·5 W.	......	......	......	......	......	......	Belcher.
Floe, Baring Bay	75 37	267 52	1853·5	144 58 W.	......	145·0 W.	......	......	......	......	......	......	Belcher.
Buckingham Island	77 10	268 53	1853·5	142 47 W.	......	142·8 W.	......	......	......	......	......	......	Belcher.
On ice	76 08	281 39	1818·5	109 58 W.	......	110·0 W.	86 00	− 9	85·9	12·39	......	12·39	Sabine.
On ice	76 33	283 08	1818·5	106 08 W.	......	106·1 W.	......	......	......	......	......	......	Sabine.
Cadogan Inlet	78 11	283 32	1861·5	......	......	......	85 21	+19	85·7	......	......	......	Hayes.
On ice	76 45	284 00	1818·5	......	......	......	86 09	−24	85·8	12·45	......	12·45	Sabine.
On ice	75 46	284 11	1850·5	106 35 W.	......	106·6 W.	......	......	......	......	......	......	Ommanney.
[illegible]	76 13	285 04	1850·5	101 50 W.	......	101·8 W.	......	......	......	......	......	......	Ommanney.
On ice	76 32	286 15	1818·5	......	......	......	85 44	−24	85·3	......	......	......	Sabine.
Lyttelton Island	78 22	286 30	1861·5	......	......	......	84 43	+19	85·0	......	......	......	Hayes.
Hakluyt Island	77 23	286 50	1861·5	......	......	......	85 00	+19	85·3	......	......	......	Hayes.
Starr Island	78 18	286 54	1861·5	109 45 W.	......	109·8 W.	......	......	......	......	......	......	Hayes.
Camp Hawks	79 44	286 54	1861·5	115 38 W.	......	115·6 W.	......	......	......	......	......	......	Hayes.
[illegible]	76 43	286 58	1851·5	......	......	......	84 59	+ 9	85·2	......	......	......	R. C. Allen.
Port Foulke	78 18	287 00	1861·5	111 40 W.	......	111·7 W.	85 02	+19	85·4	12·52	......	12·52	Hayes.
Cairn Point	78 31	287 01	1861·5	110 09 W.	......	110·2 W.	......	......	......	......	......	......	Hayes.
[illegible] Camp	79 30	287 07	1861·5	113 00 W.	......	113·0 W.	......	......	......	......	......	......	Hayes.
Cary Islands	76 45	287 14	1850·5	......	......	......	85 19	+ 8	85·5	12·22	......	12·22	Ommanney.
On ice	76 30	287 25	1818·5	102 27 W.	......	102·5 W.	......	......	......	......	......	......	Sabine.
Potato Camp	79 04	287 30	1861·5	105 34 W.	......	105·6 W.	......	......	......	......	......	......	Hayes.
Northumberland Isl^d.	77 11	287 40	1861·5	106 00 W.	......	106·0 W.	......	......	......	......	......	......	Hayes & Radcliff.
Camp Separation	78 53	287 52	1861·5	105 04 W.	......	105·1 W.	......	......	......	......	......	......	Hayes.
Last Camp	78 38	287 52	1861·5	108 36 W.	......	108·6 W.	......	......	......	......	......	......	Hayes.
Cape Grinnell	78 34	288 26	1853·5	......	......	......	85 08	+11	85·3	......	......	......	Kane.
Foggy Camp	79 55	288 32	1861·5	106 53 W.	......	106·9 W.	......	......	......	......	......	......	Hayes.
On ice	75 25	288 38	1850·5	......	......	......	84 17	+ 8	84·4	......	......	......	Ommanney.
Netlik	77 08	288 38	1861·5	106 49 W.	......	106·8 W.	84 58	+19	85·3	12·65	......	12·65	Hayes.
Observatory, Rensselaer Harbour	78 37	289 20	1854·5	108 12 W.	......	108·2 W.	84 46	+12	85·0	12·48	......	12·48	Kane.
Ice off Wolstenholme Island	76 19	290 30	1850·5	......	......	......	84 56	+ 8	85·1	......	......	......	Ommanney.

ZONE VIII.—Lat. 75° to 85° N. (continued).

Stations.	Lat. N.	Long. E.	Date.	Declination. Observed.	Correction to Epoch 1842·5.	Corrected.	Inc[illegible] Observed.	Cor. to Epoch 1842·5.	Corrected.	[illegible] Observed.	Cor. to Epoch 1842·5.	Corrected.	Observers.
	° ′	° ′		° ′		°	° ′	′	°				
Marshall Bay	78 52	291 00	1853·5	......	......	......	84 49	+11	85·0	......	......	......	Kane.
On ice	75 55	294 30	1818·5	93 40 w.	......	93·7 w.	......	......	......	......	......	......	Sabine.
[illegible]	76 05	294 30	1853·5	......	......	......	......	......	......	12·58	......	12·58	Bellot.
[illegible]	75 31	294 40	1857·5	......	......	......	84 04	+15	84·3	......	......	......	M'Clintock.
[illegible] of three observations	75 23	294 40	1857·5	94 40 w.	......	94·7 w.	......	......	......	......	......	......	M'Clintock.
[illegible] ...	75 59	295 13	1818·5	......	......	......	84 52	−24	84·5	......	......	......	Sabine.
[illegible] ...	75 54	295 27	1818·5	90 43 w.	......	90·7 w.	84 52	−24	84·5	......	......	......	Sabine.
[illegible]	75 28	295 54	1857·5	......	......	......	83 51	+15	84·1	......	......	......	M'Clintock.
On ice	75 45	296 00	1818·5	88 57 w.	......	89·0 w.	......	......	......	......	......	......	Sabine.
Skene Isl[illegible]	7[illegible]	296 30	1853·5	......	......	......	84 10	+11	84·4	......	......	......	Bellot.
On ice	75 51	296 54	1818·5	......	......	......	84 44	−24	84·4	12·09	......	12·09	Sabine.
On ice	75 31	297 37	1848·5	......	......	......	83 27	......	......	......	......	......	Robinson.
[illegible]	75 2[illegible]	298 13	1850·5	......	......	......	84 16	+ 8	84·4	......	......	......	R. C. Allen.
[illegible]	[illegible]	298 16	1850·5	88 51 w.	......	88·9 w.	......	......	......	11·84	......	11·84	Ommanney.
[illegible]	[illegible]	298 19	1852·5	89 24 w.	......	89·4 w.	84 27	+10	84·6	......	......	......	Belcher.
On ice	76 19	298 30	1850·5	101 14 w.	......	101·2 w.	......	......	......	......	......	......	Ommanney.
On ice, Melville Bay ..	75 25	298 35	1850·5	......	......	......	84 17	+ 8	84·4	......	......	......	Ommanney.
On ice	75 18	298 41	1852·5	88 42 w.	......	88·7 w.	......	......	......	......	......	......	Kellett.
On ice	75 22	298 50	1850·5	89 20 w.	......	89·3 w.	84 06	+ 8	84·2	......	......	......	Ommanney.
On ice, Melville Bay ...	75 21	298 51	1850·5	......	......	......	84 04	+ 8	84·2	......	......	......	Ommanney.
On ice, Baffin's Bay ...	75 22	298 54	1850·5	......	......	......	84 02	+ 8	84·2	......	......	......	R. C. Allen.
On ice	75 22	298 55	1852·5	89 12 w.	......	89·2 w.	......	......	......	......	......	......	Kellett and Allen.
On ice, Melville Bay...	75 32	299 00	1818·5	87 55 w.	......	87·9 w.	......	......	......	......	......	......	Sabine.
On ice, Melville Bay...	75 21	299 00	1850·5	......	......	......	84 12	+ 8	84·3	......	......	......	Ommanney.
On ice	75 28	299 25	1818·5	88 19 w.	......	88·3 w.	......	......	......	......	......	......	Sabine.
On ice	75 01	299 51	1852·5	87 08 w.	......	87·1 w.	83 52	+10	84·0	......	......	......	Belcher.
On ice	75 04	299 57	1818·5	87 00 w.	......	87·0 w.	84 25	−24	84·0	11·88	......	11·88	Sabine.
Sabine Islands, land ice	75 25	300 10	1853·5	......	......	......	83 42	+11	83·9	......	......	......	Bellot.
Browne's Islands	75 12	301 00	1848·5	......	......	......	84 04	......	84·1	......	......	......	Robinson.
On ice, S. of Browne's Islands	75 00	301 00	1857·5	......	......	......	83 28	+15	83·7	......	......	......	M'Clintock.
On ice, near Cape Seddon	75 10	301 00	1853·5	......	......	......	......	......	......	12·22	......	12·22	Bellot.

The earliest conclusion of a systematic character regarding the phenomena of Terrestrial Magnetism, which is consistent with, and has been borne out by, our more recent as well as by our present knowledge, is that of HALLEY, contained in a paper presented to the Royal Society in 1683; in which paper he demonstrated the impossibility of reconciling the magnetic Declinations which had been observed by "persons of good skill and integrity" in different parts of the globe (of which Declinations he subjoined a Table), with the Theory, then recently proposed, of "Two Magnetical Poles, and an axis inclined to the Axis of the Earth." Subsequent experience has abundantly confirmed the soundness of HALLEY'S conclusion. The Records of Navigators and of Travellers, in the nearly two centuries which have since elapsed, have practically demonstrated its truth. Slowly as conviction may have made its way, there are probably few remaining (who have studied with due care the researches of the past and of the present centuries) who still hesitate to accept the conclusion to which HALLEY was led by the careful study of the Phenomena as they were then known—viz. that "the Globe of the Earth may be regarded as one great magnet, having Four Magnetical Poles, or Points of Attraction, two of them near each Pole of the Equator; and that in those parts of the world which lie near any of those magnetical Poles, the needle is chiefly governed thereby, the nearest pole being always predominant over the more remote."

HANSTEEN, in his memorable work, the 'Magnetismus der Erde,' published in 1819, brought together the observations of the Declination which had been previously scattered in voyages and travels and in the works of systematic writers (including those which had been collected by HALLEY), and formed from them maps of the phenomena corresponding to successive Epochs. Copies of the greater part of these maps were published in an abstract of the contents of the 'Magnetismus der Erde' which I drew up for the British Association for the Advancement of Science in 1835, and which was printed in the Report of the Dublin Meeting of the Association for that year. The first of these maps, corresponding to the observations of the Declination between 1600 and 1700, is the earliest digest of contemporary determinations sufficiently extensive to warrant general conclusions. The present contribution may be regarded as a progressive step in the work thus commenced by HALLEY and continued by HANSTEEN—a continuation in the same direction as that pursued by the two authorities whose footsteps I have endeavoured to follow, but with resources which attest the increased importance which has since attached to the subject.

The amount of "new material" which has accumulated since the publication of the 'Magnetismus der Erde' in 1819, abundantly testifies the increased interest with which this branch of Physical Geography has been since, and is now, regarded. The knowledge which we have since acquired of the magnetic phenomena in the northern portions of both the old and the new Continents may well be regarded as constituting an era in the history of its progressive advancement. What has been achieved for the northern parts of Europe and Asia by the researches of the eminent men who have made that field of research their own, has been paralleled in the New World by the prominence which

has been assigned to Magnetical Observations in the successive Polar Voyages, and by the assiduous labours of British Naval and Military Officers, and of the Magneticians of the United States, acting in concert with the operations of the Coast Survey. The earliest authoritative knowledge we possess of the magnetical state of the North-American Continent was contained in the same communication from HALLEY to the Royal Society in 1683 to which reference has already been made. In that paper, the Geographical Position of the "North-American Magnetic Pole" is stated to be in "a meridian corresponding with the middle of California," and "about 15° from the North Pole of the Globe." We have, indeed, no assured knowledge as to whether the Geographical Position thus indicated was designed by HALLEY to refer to the locality characterized by "90° of Inclination," or to that of the "Maximum of Force,"—the distinction between these two localities being well known to HALLEY, as it was, in fact, established by himself. Our recent researches place the approximate localities of these points, in 1842·5,—that of the maximum of Inclination in 70° N. Latitude and 263° E. Longitude; whilst for the Maximum of Force we have the Latitude 53° N. and Longitude 268° E.,—both localities being to the East, and a little to the South, of the Geographical Position which HALLEY assigned to the Magnetic Pole in 1683. Admitting the probability, which appears to be generally recognized and acceded to, that the Easterly Progression terminated at an Epoch nearly coinciding with that of the Maps and Tables of the present memoir, viz. 1842·5, such probability may seem to render the present occasion a particularly suitable one for subjoining a few "Groups" of Results (as proposed in a previous page, p. 356) for convenient comparison with the Phenomena which may be observed at future periods.

Declination.

1. McClure. Epoch 1851·5.

Lat. N.	Long. E.	Declination E.
° ′	° ′	° ′
71 06	237 00	80 14
74 27	237 29	86 24
74 06	241 15	96 14
72 47	242 26	83 01
73 05	243 54	89 16
73 12	244 17	93 12
73 07	241 09	88 01 E.

2. Sabine. Epoch 1819–1820.

Lat. N.	Long. E.	Declination E.
° ′	° ′	° ′
74 26	216 12	106 07
74 21	217 07	110 56
74 25	217 19	111 19
74 27	217 49	114 35
75 05	218 03	123 18
75 13	218 10	125 15
74 40	217 25	115 20 E.

3. Sabine. Epoch 1819–1820.

Lat. N.	Long. E.	Declination E.
° ′	° ′	° ′
74 27	218 18	117 52
75 03	218 23	126 02
74 19	218 48	123 06
74 47	219 12	127 48
74 17	219 26	126 17
75 21	219 27	131 47
74 52	218 56	125 29 E.

4. Ommanney. Epoch 1850–1851.

Lat. N.	Long. E.	Declination E.
° ′	° ′	° ′
73 01	258 17	168 46
73 00	258 21	169 07
73 03	258 52	170 57
73 37	258 55	172 00
73 06	259 08	171 38
73 09	258 43	170 28 E.

5. Ommanney. Epoch 1850–1851.

Lat. N.	Long. E.	Declination W.
° ′	° ′	° ′
74 01	259 53	166 20
73 55	260 35	163 25
73 59	260 51	159 02
74 03	261 55	166 09
74 00	260 45	163 47 W.

6. Belcher. Epoch 1852·5.

Lat. N.	Long. E.	Declination W.
° ′	° ′	° ′
75 51	263 00	156 47
76 57	263 05	155 23
76 43	263 15	146 12
75 28	264 00	152 00
75 27	264 05	152 27
77 16	264 10	155 12
76 47	263 36	152 15 W.

7. Belcher. Epoch 1853·5.

Lat. N.	Long. E.	Declination W.
° ′	° ′	° ′
77 00	264 57	146 42
77 31	265 03	154 20
76 04	265 15	153 17
76 16	265 15	151 38
76 56	265 32	154 15
76 58	265 40	147 43
76 52	266 23	149 28
76 49	265 26	151 03 W.

8. Hayes. Epoch 1861·5.

Lat. N.	Long. E.	Declination W.
° ′	° ′	° ′
78 18	286 54	109 45
79 44	286 54	115 38
78 18	287 00	111 40
78 31	287 01	110 09
79 30	287 07	113 00
79 04	287 30	105 34
78 54	287 04	110 58 W.

9. Sabine. Epoch 1818·5.

Lat. N.	Long. E.	Declination W.
° ′	° ′	° ′
75 55	294 30	93 40
75 54	295 27	90 43
75 45	296 00	88 57
75 32	299 00	87 55
75 28	299 25	88 19
75 04	299 57	87 00
75 36	297 23	89 26 W.

10. Various Observers. Approx. General Epoch 1851·5.

	Lat. N.	Long. E.	Declination W.
	° ′	° ′	° ′
McClintock	75 23	294 40	94 40
Belcher	75 23	298 19	89 24
Ommanney	75 51	298 23	95 02
Kellett	75 18	298 41	88 42
Ommanney	75 22	298 50	89 20
Kellett	75 22	298 55	89 12
Belcher	75 04	299 51	87 08
	75 23	298 14	90 30 W.

Inclination.

1. Sabine. Epoch 1819–1820.			2. Simpson. Epoch 1839.			3. M^cClintock. Epoch 1859.		
Lat. N.	Long. E.	Inclination N.	Lat. N.	Long. E.	Inclination N.	Lat. N.	Long. E.	Inclination N.
° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
74 27	248 18	88 37	68 56	253 20	88 15	69 08	259 55	89 26
74 47	249 12	88 42	68 07	256 23	88 20	68 42	261 50	89 35
74 47	249 26	88 30	68 41	261 38	89 29	68 31	262 50	89 24
74 55	255 18	88 29	68 21	262 35	89 30	67 50	263 23	89 32
75 10	256 16	88 26				67 58	263 40	89 08
						69 32	263 50	89 51
74 49	251 48	88 33 N.	68 31	258 29	88 51 N.	68 37	262 35	89 29 N.

4. M^cClintock. Epoch 1859.			5. M^cClintock. Epoch 1859.			6. James Ross. Epoch 1831·5.		
Lat. N.	Long. E.	Inclination N.	Lat. N.	Long. E.	Inclination N.	Lat. N.	Long. E.	Inclination N.
° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
69 37	261 19	89 45	71 08	263 30	89 13	70 05	263 41	89 59
69 41	262 50	89 55	71 25	264 00	89 01	69 35	265 07	89 42
70 11	263 15	89 52	71 59	264 52	88 12	69 26	266 09	89 22
70 07	263 25	89 49	72 01	265 10	88 27	69 30	266 32	89 17
70 33	263 30	89 13	72 01	265 49	88 23	70 01	268 06	89 00
70 49	263 30	89 16				70 09	268 29	88 55
70 09	262 58	89 38 N.	71 43	264 46	88 39 N.	69 48	266 16	89 22 N.

7. James Ross and Ommanney. Epoch 1850.			8. Parry and Fisher. Epoch 1821–1822.			9. Parry and Fisher. Epoch 1821–1822.		
Lat. N.	Long. E.	Inclination N.	Lat. N.	Long. E.	Inclination N.	Lat. N.	Long. E.	Inclination N.
° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
O. 74 36	264 42	87 48	66 31	273 30	88 07	69 48	276 31	88 21
R. 74 01	264 49	88 14	65 30	274 45	87 28	69 21	278 23	88 10
O. 74 35	264 50	87 58	66 13	275 20	87 31	69 32	278 37	88 06
O. 74 43	266 41	87 34	66 38	275 49	87 52	69 34	278 46	87 37
R. 74 08	267 09	87 36	66 12	277 06	87 51			
R. 74 00	267 57	87 44	66 56	278 21	87 47			
R. 74 02	268 53	87 36	65 08	280 25	87 09			
74 18	266 26	87 47 N.	66 10	276 28	87 41 N.	69 34	278 04	88 03 N.

10. Sabine. Epoch 1818.			11. Kane and Hayes. Epoch 1854–1861.			12. Allen and Ommanney. Epoch 1851.		
Lat. N.	Long. E.	Inclination N.	Lat. N.	Long. E.	Inclination N.	Lat. N.	Long. E.	Inclination N.
° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
76 08	281 39	86 00	H. 78 11	283 32	85 21	A. 76 43	286 58	84 50
73 31	282 38	86 04	H. 78 22	286 30	84 43	O. 76 45	287 14	85 19
76 45	284 00	86 09	H. 77 23	286 50	85 00	O. 75 25	288 38	84 17
76 32	286 15	85 44	H. 78 18	287 00	85 02	O. 76 19	290 30	84 56
			K. 78 34	288 26	85 08			
			H. 77 08	288 38	84 58			
			K. 78 37	289 20	84 46			
			K. 78 52	291 00	84 49			
75 44	283 38	85 59 N.	78 11	287 39	84 58 N.	76 18	288 20	84 53 N.

Inclination (continued).

13. Various Observers. Epoch 1853.				14. Sabine. Epoch 1818.		
	Lat. N.	Long. E.	Inclination N.	Lat. N.	Long. E.	Inclination N.
	° ′	° ′	° ′	° ′	° ′	° ′
McClintock	75 31	294 40	84 04	75 59	295 13	84 52
McClintock	75 28	295 54	83 51	75 54	295 27	84 52
Bellot...............	76 00	296 30	84 10	75 51	296 54	84 44
Robinson	75 34	297 37	83 27	75 04	299 57	84 25
Allen	75 26	298 13	84 16	74 35	301 02	83 51
Belcher	75 23	298 19	84 27	74 01	302 08	84 09
	75 34	296 52	84 02 N.	75 14	298 27	84 29 N.

15. Various Observers. Epoch 1850.				16. Various Observers. Epoch 1850.			
	Lat. N.	Long. E.	Inclination N.		Lat. N.	Long. E.	Inclination N.
	° ′	° ′	° ′		° ′	° ′	° ′
Ommanney	75 25	298 38	84 17	Robinson	75 12	301 00	84 04
Ommanney	75 22	298 50	84 06	McClintock	75 00	301 00	83 28
Ommanney	75 21	298 54	84 04	Brown	74 35	301 02	83 51
Allen	75 22	298 54	84 02	Brown	74 35	301 13	84 00
Ommanney	75 21	299 00	84 12	Allen	74 35	301 13	83 49
Belcher	75 04	299 51	83 52	Ommanney	74 35	301 13	83 35
Bellot...............	75 25	300 10	83 42	Allen	74 01	302 08	83 47
	75 20	299 11	84 02 N.		74 39	301 16	83 48 N.

The Observations of the Force, in the portion of the Globe for which I have given groups of the other two Elements (viz. Arctic America for about fifty degrees of Longitude), are scarcely sufficiently numerous to receive the same mode of treatment. I have therefore merely assembled these observations in a separate List, arranged according to Longitude.

Date.	Observers.	Lat. N.	Long. E.	Force.	Date.	Observers.	Lat. N.	Long. E.	Force.
		° ′	° ′				° ′	° ′	
1819	Sabine	74 27	248 18	12·13	1861	Hayes.....................	77 08	288 38	12·65
1820	Sabine	74 47	249 12	12·24	1854	Kane	78 37	289 20	12·48
1819	Sabine	75 10	256 16	12·35	1818	Sabine	70 35	293 05	12·41
1851	Ommanney	74 36	264 42	12·39	1853	Bellot	76 05	294 30	12·58
1850	Ommanney	74 43	266 41	12·33	1818	Sabine	75 51	296 54	12·09
1853	Bellot	74 42	268 17	12·72	1850	Ommanney	75 24	298 16	11·84
1849	Robinson and Brown..	73 52	269 43	13·05	1818	Sabine	75 04	299 57	11·88
1819	Sabine	72 45	270 19	12·46	1853	Bellot	75 10	301 00	12·22
1825	Parry and Foster	73 14	271 05	13·26	1850	Ommanney	74 35	301 13	12·00
1853	Bellot	74 35	277 45	12·91	1850	Ommanney	73 10	303 36	12·21
1818	Sabine	76 08	281 39	12·39	1861	Hayes.....................	72 47	303 57	12·38
1819	Parry and Sabine	73 31	282 38	12·23	1853	Kane	72 23	304 30	12·84
1818	Sabine	76 45	284 00	12·45	1818	Sabine	70 26	305 08	12·12
1861	Hayes.....................	78 18	287 00	12·52	1823	Sabine	74 32	341 10	11·54
1850	Ommanney	76 45	287 14	12·22					

In the following Tables I have placed, in comparison with each other, the values of the magnetic Elements at every fifth degree of Latitude between 40° N. and 90° N., and at every tenth degree of Longitude between 0° and 360°, as shown, 1°, in the Table pub-

lished by MM. GAUSS and WEBER, in the 'Atlas des Erdmagnetismus' (Leipsic, 1840); and 2°, in the Tables and Maps of the present paper. For the values of the magnetic Force, which in the Atlas of MM. GAUSS and WEBER are expressed in the Arbitrary Scale, of which the fundamental value is 1·372, or (as written by M. GAUSS) 1372 = the Force in London in 1836, I have substituted the Absolute Values, corresponding to 10·28 as the Absolute Force in London at the same Epoch, in the scale which was originally adopted in conformity with the Report of the Committee of Physics of the Royal Society, 1840, page 21*. In all the three Elements there are some blanks in the columns derived from the data in the present paper, owing to observations being either wanting or insufficient in those localities. *Some* of these blanks, viz. those in the vicinity of the Pole of the Earth, it will, probably, never be possible to fill up; but many of those in Lats. 40° and 45° may probably be supplied, when the evidence which this paper affords is supplemented by results South of 40° of N. Latitude, which are now in hand.

* The Section of the Report in which the Scale is premised, in which the values of the magnetic Force should thenceforward be expressed, generally known as the "Scale of British Units," was from the pen of its Chairman, the late Sir JOHN HERSCHEL, Bart.; the Scale is thus defined by him:—"The number thus obtained, for the Force of the Earth's Magnetism, expresses the Ratio which that Force bears to the *Unit of Force*; the Unit of Force being that which acting on the Unit of *Mass*, through the Unit of *Time*, generates in it the unit of *Velocity*. For the unit of Mass we take, a *grain*; for the unit of Time, a *second*; and if a Foot be taken as the unit of *Space*, the unit of *Velocity* will be that of one foot per second."

Declination.

Latitudes.	Gauss.	Sabine.	Gauss.	Sabine.	Gauss.	Sabine.	Gauss.	Sabine.	Gauss.	Sabine.	Gauss.	Sabine.	Latitudes.
	Long. 0° E.		Long. 10° E.		Long. 20° E.		Long. 30° E.		Long. 40° E.		Long. 50° E.		
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	°
85 N.	46 03 W.	......	37 17 W.	......	29 47 W.	......	20 54 W.	......	13 19 W.	......	6 07 W.	......	85 N.
80 N.	36 00 W.	32 30 W.	28 00 W.	23 55 W.	20 28 W.	14 35 W.	13 16 W.	4 00 W.	6 40 W.	4 45 E.	0 41 W.	11 00 E.	80 N.
75 N.	31 09 W.	30 30 W.	23 39 W.	22 30 W.	16 28 W.	13 00 W.	9 45 W.	4 00 W.	3 37 W.	4 00 E.	1 46 E.	10 00 E.	75 N.
70 N.	28 39 W.	29 00 W.	21 34 W.	21 30 W.	14 46 W.	12 30 W.	8 17 W.	4 00 W.	2 26 W.	3 00 E.	2 36 E.	8 50 E.	70 N.
65 N.	27 17 W.	27 00 W.	20 40 W.	20 10 W.	14 08 W.	12 25 W.	7 55 W.	4 40 W.	2 16 W.	1 50 E.	2 33 E.	7 20 E.	65 N.
60 N.	26 29 W.	26 00 W.	20 22 W.	19 30 W.	14 10 W.	12 25 W.	8 09 W.	5 15 W.	2 39 W.	0 40 E.	2 03 E.	5 25 E.	60 N.
55 N.	25 54 W.	24 20 W.	20 22 W.	18 40 W.	14 33 W.	12 30 W.	8 43 W.	6 15 W.	3 19 W.	0 40 W.	1 20 E.	3 35 E.	55 N.
50 N.	25 23 W.	23 10 W.	20 29 W.	18 00 W.	15 02 W.	12 30 W.	9 26 W.	7 10 W.	4 07 W.	2 15 W.	0 32 E.	1 45 E.	50 N.
45 N.	24 52 W.	21 45 W.	20 38 W.	17 00 W.	15 37 W.	12 35 W.	10 14 W.	8 00 W.	4 58 W.	3 25 W.	0 16 W.	0 20 E.	45 N.
40 N.	24 20 W.	20 35 W.	20 48 W.	17 00 W.	16 13 W.	13 00 W.	11 03 W.	8 50 W.	5 49 W.	4 25 W.	1 04 W.	0 45 W.	40 N.
	Long. 60° E.		Long. 70° E.		Long. 80° E.		Long. 90° E.		Long. 100° E.		Long. 110° E.		
85 N.	0 38 E.	......	7 00 E.	......	12 58 E.	......	18 37 E.	......	23 58 E.	......	30 13 E.	......	85 N.
80 N.	4 35 E.	16 40 E.	9 03 E.	......	12 40 E.	......	15 26 E.	30 30 E.	17 28 E.	......	19 07 E.	......	80 N.
75 N.	6 13 E.	15 25 E.	9 36 E.	20 00 E.	11 45 E.	24 00 E.	12 40 E.	23 00 E.	12 33 E.	20 00 E.	11 51 E.	18 25 E.	75 N.
70 N.	6 35 E.	14 00 E.	9 19 E.	17 30 E.	10 38 E.	19 00 E.	10 24 E.	17 20 E.	9 02 E.	14 20 E.	7 07 E.	10 35 E.	70 N.
65 N.	6 17 E.	12 00 E.	8 38 E.	15 20 E.	9 27 E.	15 50 E.	8 39 E.	13 50 E.	6 37 E.	9 15 E.	4 07 E.	4 30 E.	65 N.
60 N.	5 39 E.	10 00 E.	7 50 E.	12 30 E.	8 24 E.	13 00 E.	7 20 E.	10 55 E.	5 00 E.	6 30 E.	2 18 E.	1 30 E.	60 N.
55 N.	4 53 E.	7 20 E.	7 01 E.	10 00 E.	7 31 E.	10 25 E.	6 23 E.	8 25 E.	4 01 E.	4 35 E.	1 14 E.	0 00	55 N.
50 N.	4 07 E.	4 35 E.	6 16 E.	......	6 48 E.	7 00 E.	5 42 E.	......	3 24 E.	3 20 E.	0 41 E.	0 15 W.	50 N.
45 N.	3 23 E.	3 00 E.	5 37 E.	......	6 14 E.	......	5 14 E.	......	3 03 E.	......	0 26 E.	0 25 W.	45 N.
40 N.	2 42 E.	......	4 56 E.	......	5 47 E.	......	4 55 E.	......	2 52 E.	......	0 24 E.	0 30 W.	40 N.
	Long. 120° E.		Long. 130° E.		Long. 140° E.		Long. 150° E.		Long. 160° E.		Long. 170° E.		
85 N.	34 22 E.	......	39 42 E.	......	45 27 E.	......	51 30 E.	......	58 16 E.	......	65 50 E.	......	85 N.
80 N.	20 30 E.	......	22 15 E.	......	24 38 E.	......	27 53 E.	......	32 06 E.	......	37 17 E.	......	80 N.
75 N.	11 14 E.	16 30 E.	11 19 E.	15 30 E.	12 29 E.	16 00 E.	14 53 E.	17 45 E.	18 26 E.	20 00 E.	22 58 E.	26 15 E.	75 N.
70 N.	5 30 E.	7 00 E.	4 56 E.	5 05 E.	5 44 E.	6 10 E.	8 00 E.	9 00 E.	11 27 E.	13 00 E.	15 50 E.	17 50 E.	70 N.
65 N.	2 05 E.	0 00	1 17 E.	1 00 W.	2 02 E.	0 20 W.	4 15 E.	3 35 E.	7 40 E.	8 20 E.	11 57 E.	14 00 E.	65 N.
60 N.	0 06 E.	1 30 W.	0 46 W.	3 15 W.	0 04 W.	2 00 W.	2 10 E.	1 00 E.	5 33 E.	5 40 E.	9 41 E.	11 10 E.	50 N.
55 N.	0 59 W.	2 40 W.	1 53 W.	5 25 W.	1 11 W.	3 25 W.	1 01 E.	0 00	4 21 E.	4 35 E.	8 28 E.	10 02 E.	55 N.
50 N.	1 30 W.	3 40 W.	2 23 W.	......	1 42 W.	3 40 W.	0 28 E.	0 30 W.	3 52 E.	4 25 E.	7 44 E.	9 30 E.	50 N.
45 N.	1 39 W.	......	2 30 W.	......	1 49 W.	3 50 W.	0 19 E.	0 30 W.	3 32 E.	4 05 E.	7 22 E.	9 15 E.	45 N.
40 N.	1 34 W.	......	2 21 W.	......	1 39 W.	......	0 27 E.	......	3 35 E.	4 10 E.	7 15 E.	......	40 N.
	Long. 180° E.		Long. 190° E.		Long. 200° E.		Long. 210° E.		Long. 220° E.		Long. 230° E.		
[illegible]	[illegible]	......	[illegible]	......	[illegible]	......	[illegible]	......	[illegible]		[illegible]	......	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	......	[illegible]
75 N.	28 17 E.	34 00 E.	34 14 E.	40 35 E.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
70 N.	20 51 E.	24 45 E.	26 15 E.	31 00 E.	31 49 E.	36 25 E.	37 14 E.	42 00 E.	42 22 E.	47 45 E.	46 50 E.	54 00 E.	70 N.
65 N.	16 47 E.	19 20 E.	21 48 E.	25 20 E.	26 42 E.	29 30 E.	31 14 E.	33 50 E.	35 04 E.	38 10 E.	37 48 E.	42 00 E.	65 N.
60 N.	14 23 E.	16 25 E.	19 03 E.	21 30 E.	23 25 E.	25 50 E.	27 13 E.	28 30 E.	30 06 E.	31 00 E.	31 39 E.	33 00 E.	60 N.
55 N.	12 53 E.	14 20 E.	17 12 E.	18 50 E.	21 07 E.	22 45 E.	24 13 E.	25 15 E.	26 21 E.	26 30 E.	27 09 E.	27 00 E.	55 N.
50 N.	11 55 E.	......	15 53 E.	16 50 E.	19 16 E.	20 20 E.	21 49 E.	22 30 E.	23 18 E.	23 20 E.	23 35 E.	23 25 E.	50 N.
45 N.	11 18 E.	......	14 53 E.	15 10 E.	17 46 E.	18 20 E.	19 45 E.	19 45 E.	20 44 E.	20 25 E.	20 38 E.	20 05 E.	45 N.
40 N.	10 55 E.	......	14 05 E.	......	16 28 E.	......	17 56 E.	......	18 28 E.	......	18 08 E.	......	40 N.
	Long. 240° E.		Long. 250° E.		Long. 260° E.		Long. 270° E.		Long. 280° E.		Long. 290° E.		
85 N.	153 27 E.	......	171 20 E.	......	170 42 W.	......	153 33 W.	......	137 32 W.	......	123 47 W.	......	85 N.
80 N.	114 04 E.	......	143 22 E.	......	179 00 W.	......	146 01 W.	......	123 05 W.	122 00 W.	106 56 W.	......	80 N.
75 N.	71 52 E.	94 00 E.	84 38 E.	130 00 E.	125 42 E.	......	119 53 W.	132 30 W.	99 16 W.	109 30 W.	88 19 W.	98 30 W.	75 N.
70 N.	49 53 E.	62 15 E.	49 22 E.	70 00 E.	35 27 E.	75 30 E.	39 55 W.	93 30 W.	63 25 W.	90 30 W.	68 07 W.	85 30 W.	70 N.
65 N.	38 23 E.	43 40 E.	35 12 E.	43 00 E.	23 46 E.	32 35 E.	2 31 W.	30 00 W.	32 50 W.	56 20 W.	48 09 W.	64 20 W.	65 N.
60 N.	31 15 E.	34 00 E.	27 42 E.	32 45 E.	19 06 E.	23 00 E.	3 33 E.	5 00 W.	16 10 W.	33 00 W.	32 13 W.	47 20 W.	60 N.
55 N.	26 13 E.	27 00 E.	22 53 E.	25 35 E.	16 18 E.	19 00 E.	5 49 E.	4 00 E.	7 38 W.	16 40 W.	20 48 W.	30 10 W.	55 N.
50 N.	22 24 E.	22 45 E.	19 27 E.	20 40 E.	14 21 E.	16 45 E.	6 49 E.	7 30 E.	2 48 W.	8 00 W.	13 06 W.	19 35 W.	50 N.
45 N.	19 24 E.	19 15 E.	16 53 E.	17 40 E.	12 54 E.	......	7 16 E.	8 00 E.	0 08 E.	3 00 W.	7 54 W.	13 00 W.	45 N.
40 N.	16 57 E.	......	14 52 E.	14 45 E.	11 45 E.	......	7 29 E.	......	2 03 E.	0 00	4 20 W.	......	40 N.
	Long. 300° E.		Long. 310° E.		Long. 320° E.		Long. 330° E.		Long. 340° E.		Long. 350° E.		
85 N.	109 32 W.	......	97 13 W.	......	85 39 W.	......	75 01 W.	......	64 52 W.	......	55 15 W.	......	85 N.
80 N.	93 23 W.	92 30 W.	82 02 W.	77 30 W.	71 47 W.	63 00 W.	62 12 W.	54 00 W.	53 05 W.	45 45 W.	44 22 W.	......	80 N.
75 N.	79 17 W.	86 00 W.	70 54 W.	74 00 W.	62 45 W.	61 30 W.	54 43 W.	53 00 W.	46 45 W.	45 35 W.	38 52 W.	38 00 W.	75 N.
70 N.	66 02 W.	78 00 W.	61 17 W.	70 00 W.	55 53 W.	58 40 W.	49 36 W.	51 15 W.	42 49 W.	44 15 W.	35 40 W.	36 10 W.	70 N.
65 N.	53 04 W.	66 40 W.	52 07 W.	62 30 W.	49 26 W.	55 00 W.	45 21 W.	48 30 W.	39 53 W.	41 40 W.	33 49 W.	34 10 W.	65 N.
60 N.	40 57 W.	53 00 W.	44 09 W.	53 00 W.	43 51 W.	49 20 W.	41 19 W.	43 50 W.	*	38 00 W.	32 09 W.	32 05 W.	60 N.
55 N.	30 29 W.	39 57 W.	35 55 W.	43 00 W.	37 53 W.	42 00 W.	37 15 W.	39 10 W.	34 43 W.	34 40 W.	30 48 W.	29 55 W.	55 N.
50 N.	22 08 W.	29 40 W.	28 34 W.	34 50 W.	32 09 W.	36 00 W.	33 10 W.	34 45 W.	32 06 W.	31 50 W.	29 22 W.	28 00 W.	50 N.
45 N.	15 46 W.	21 30 W.	22 20 W.	27 20 W.	26 53 W.	29 30 W.	29 13 W.	29 30 W.	29 29 W.	28 15 W.	27 56 W.	25 40 W.	45 N.
40 N.	11 03 W.	15 35 W.	17 17 W.	......	22 17 W.	......	25 34 W.	......	26 57 W.	......	26 29 W.	......	40 N.

* Error in orig.

Inclination.

Latitudes.	Gauss. Long. 0° E.	Sabine. Long. 0° E.	Gauss. Long. 10° E.	Sabine. Long. 10° E.	Gauss. Long. 20° E.	Sabine. Long. 20° E.	Gauss. Long. 30° E.	Sabine. Long. 30° E.	Gauss. Long. 40° E.	Sabine. Long. 40° E.	Gauss. Long. 50° E.	Sabine. Long. 50° E.	Latitudes.
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	°
85 N.	84 20	......	84 12	......	84 07	......	84 05	......	84 06	......	84 10	......	85 N.
80 N.	82 24	81 30	82 07	......	81 59	81 00	81 55	81 00	81 59	81 05	82 08	......	80 N.
75 N.	80 20	79 25	79 54	79 00	79 37	78 55	79 31	78 50	79 35	79 00	79 49	79 25	75 N.
70 N.	78 12	77 20	77 32	76 45	77 04	76 30	76 51	76 35	76 52	76 35	77 07	77 05	70 N.
65 N.	75 58	75 10	75 00	74 30	74 16	74 05	73 51	73 55	73 45	73 55	73 59	74 12	65 N.
60 N.	73 34	73 00	72 13	72 15	71 08	71 32	70 26	71 05	70 10	70 55	70 21	70 55	60 N.
55 N.	70 54	70 45	69 06	69 50	67 35	68 45	66 31	68 00	66 01	67 30	66 06	67 25	55 N.
50 N.	67 56	68 00	65 35	66 35	63 33	65 30	62 01	64 25	61 14	63 35	61 10	63 25	50 N.
45 N.	64 33	64 30	61 36	63 00	58 55	61 30	56 51	60 20	55 38	59 25	55 26	59 00	45 N.
40 N.	60 44	61 00	57 04	58 55	53 38	57 25	50 53	55 40	49 12	54 55	48 47	54 10	40 N.

	Long. 60° E.		Long. 70° E.		Long. 80° E.		Long. 90° E.		Long. 100° E.		Long. 110° E.		
85 N.	84 16	......	84 24	......	84 34	......	84 44	......	84 54	......	85 02	......	85 N.
80 N.	82 23	......	82 41	......	83 00	......	83 20	......	83 36	......	83 51	......	80 N.
75 N.	80 11	79 52	80 38	......	81 07	......	81 34	......	81 55	......	82 07	......	75 N.
70 N.	77 35	77 25	78 11	......	78 49	......	79 23	79 25	79 47	79 50	79 56	......	70 N.
65 N.	74 32	74 35	75 15	75 28	76 02	......	76 43	77 00	77 10	77 25	77 16	......	65 N.
60 N.	70 56	71 12	71 47	71 55	72 43	73 00	73 33	74 07	74 03	74 58	74 07	74 50	60 N.
55 N.	66 43	67 30	67 43	68 00	68 50	68 55	69 49	70 00	70 24	70 50	70 28	70 35	55 N.
50 N.	61 49	......	62 58	......	64 18	64 50	65 28	......	66 11	......	66 17	66 25	50 N.
45 N.	56 08	......	57 28	......	59 04	......	60 29	......	61 22	......	61 31	61 25	45 N.
40 N.	49 32	......	51 08	......	53 02	......	54 45	......	55 50	......	56 06	......	40 N.

	Long. 120° E.		Long. 130° E.		Long. 140° E.		Long. 150° E.		Long. 160° E.		Long. 170° E.		
85 N.	85 15	......	85 24	......	85 33	......	85 42	......	85 51	......	86 01	......	85 N.
80 N.	83 59	......	84 05	......	84 09	......	84 14	......	84 20	......	84 30	......	80 N.
75 N.	82 10	......	82 06	83 00	81 59	83 05	81 52	83 00	81 51	......	81 57	......	75 N.
70 N.	79 50	......	79 34	79 50	79 15	79 35	78 57	79 24	78 49	79 00	78 52	79 00	70 N.
65 N.	77 02	......	76 34	76 35	76 07	76 00	75 35	......	75 21	......	75 23	75 20	65 N.
60 N.	73 46	74 05	73 08	73 00	72 25	72 05	71 49	71 25	71 31	70 50	71 34	70 40	60 N.
55 N.	70 01	70 00	69 15	......	68 22	......	67 39	......	67 17	66 30	67 24	66 25	55 N.
50 N.	65 47	66 00	64 53	......	63 52	......	63 03	......	62 41	62 25	62 53	62 06	50 N.
45 N.	60 59	61 00	59 59	......	58 51	*59 40	57 59	......	57 38	58 00	57 58	58 00	45 N.
40 N.	55 33	......	54 28	......	53 15	......	52 21	......	52 05	53 40	52 38	54 20	40 N.

	Long. 180° E.		Long. 190° E.		Long. 200° E.		Long. 210° E.		Long. 220° E.		Long. 230° E.		
85 N.	86 12	......	86 21	......	86 42	......	86 49	......	87 00	......	87 08	......	85 N.
80 N.	84 44	......	85 05	......	85 32	......	86 03	......	86 38	......	87 16	......	80 N.
75 N.	82 14	......	82 41	......	83 17	......	84 05	......	85 01	......	86 03	......	75 N.
70 N.	79 11	79 10	79 45	79 30	80 33	80 20	81 35	81 05	82 48	82 25	84 08	83 50	70 N.
65 N.	75 46	75 30	76 29	76 00	77 30	76 55	78 46	78 15	80 13	79 45	81 49	81 25	65 N.
60 N.	72 03	71 05	72 56	72 00	74 09	73 25	75 39	75 00	77 21	76 37	79 09	78 35	60 N.
55 N.	68 01	66 45	69 06	67 50	70 33	69 27	72 17	71 22	74 10	73 15	76 08	75 25	55 N.
50 N.	63 40	62 30	64 59	63 30	66 40	65 20	68 37	67 25	70 40	69 30	72 45	71 22	50 N.
45 N.	58 59	58 30	60 33	59 40	62 30	61 17	64 38	63 30	66 49	65 30	68 57	67 25	45 N.
40 N.	53 55	55 00	55 47	56 00	57 59	57 35	60 16	59 40	62 32	61 45	64 42	......	40 N.

	Long. 240° E.		Long. 250° E.		Long. 260° E.		Long. 270° E.		Long. 280° E.		Long. 290° E.		
85 N.	87 13	......	89 35	......	87 07	......	86 56	......	86 41	......	86 27	......	85 N.
80 N.	87 51	......	88 17	......	88 21	......	87 58	......	87 20	......	86 36	85 10	80 N.
75 N.	87 11	87 15	88 21	88 20	89 28	88 40	89 01	87 30	87 50	86 30	86 39	85 15	75 N.
70 N.	85 34	85 30	87 03	87 30	88 26	88 50	88 45	89 00	87 49	87 30	86 25	85 20	70 N.
65 N.	83 28	83 20	85 05	85 15	86 30	86 30	87 16	87 40	86 54	87 30	85 42	85 15	65 N.
60 N.	80 58	80 35	82 42	82 30	84 10	84 25	85 06	85 35	85 12	85 40	84 26	84 05	60 N.
55 N.	78 04	77 15	79 52	79 30	81 24	81 25	82 29	82 35	82 54	82 50	82 34	82 00	55 N.
50 N.	74 45	73 30	76 36	75 40	78 13	77 40	79 26	79 10	80 06	79 35	80 08	79 25	50 N.
45 N.	71 00	69 20	72 53	71 30	74 33	73 30	75 54	75 20	76 49	76 00	77 10	76 25	45 N.
40 N.	66 44	65 00	68 39	67 10	70 21	69 10	71 54	71 05	73 02	72 00	73 40	......	40 N.

	Long. 300° E.		Long. 310° E.		Long. 320° E.		Long. 330° E.		Long. 340° E.		Long. 350° E.		
85 N.	86 02	......	85 42	......	85 22	......	85 03	......	84 46	......	84 32	......	85 N.
80 N.	85 51	84 22	85 07	83 35	84 26	83 00	83 48	82 25	83 14	......	82 46	......	80 N.
75 N.	85 30	84 25	84 25	83 05	83 24	82 00	82 28	81 10	81 38	80 25	80 55	79 45	75 N.
70 N.	85 00	83 55	83 37	82 20	82 21	80 55	81 09	79 40	80 02	78 37	79 02	77 52	70 N.
65 N.	84 16	83 10	82 41	81 20	81 12	79 35	79 48	78 07	78 25	77 00	77 08	75 55	65 N.
60 N.	83 10	82 00	81 38	79 55	80 01	78 10	78 22	76 30	*	75 08	75 06	73 55	60 N.
55 N.	81 36	80 25	80 12	78 25	78 33	76 35	76 44	74 55	74 49	73 17	72 51	71 45	55 N.
50 N.	79 30	78 22	78 20	76 45	76 45	75 00	74 51	73 00	72 41	71 10	70 21	69 35	50 N.
45 N.	76 53	76 00	75 59	74 50	74 32	73 00	72 36	70 57	70 13	68 37	67 30	66 25	45 N.
40 N.	73 43	......	73 07	......	71 50	70 55	69 54	68 20	67 21	65 30	64 14	63 00	40 N.

* Error in orig.

Force in British Units.

Latitudes.	Gauss.	Sabine.	Gauss.	Sabine.	Gauss.	Sabine.	Gauss.	Sabine.	Gauss.	Sabine.	Gauss.	Sabine.	Latitudes.
	Long. 0° E.		Long. 10° E.		Long. 20° E.		Long. 30° E.		Long. 40° E.		Long. 50° E.		
°													°
85 N.	12·20	......	12·19	......	12·21	......	12·21	......	12·24	......	12·28	......	85 N.
80 N.	11·97	11·7	11·97	......	11·99	......	12·03	......	12·09	......	12·16	......	80 N.
75 N.	11·72	11·5	11·73	11·5	11·75	11·5	11·82	11·5	11·92	11·7	12·03	11·9	75 N.
70 N.	11·47	11·2	11·46	11·1	11·50	11·1	11·58	11·2	11·71	11·4	11·86	11·6	70 N.
65 N.	11·23	10·9	11·18	10·9	11·21	10·9	11·31	10·9	11·46	11·1	11·66	11·4	65 N.
60 N.	10·98	10·7	10·97	10·7	10·91	10·6	11·00	10·6	11·16	10·8	11·39	11·2	60 N.
55 N.	10·73	10·5	10·60	10·4	10·57	10·4	10·63	10·3	10·80	10·6	11·05	11·0	55 N.
50 N.	10·47	10·2	10·28	10·1	10·20	10·1	10·23	10·0	10·38	10·4	10·62	10·7	50 N.
45 N.	10·17	10·0	9·92	9·9	9·79	9·8	9·77	9·9	9·89	10·1	10·12	10·3	45 N.
40 N.	9·85	......	9·53	......	9·33	......	9·28	......	9·36	......	9·57	......	40 N.
	Long. 60° E.		Long. 70° E.		Long. 80° E.		Long. 90° E.		Long. 100° E.		Long. 110° E.		
85 N.	12·31	......	12·34	......	12·37	......	12·41	......	12·44	......	12·46	......	85 N.
80 N.	12·23	......	12·31	......	12·38	......	12·45	......	12·50	......	12·54	......	80 N.
75 N.	12·15	12·1	12·28	12·2	12·39	12·5	12·49	12·6	12·56	12·8	12·61	12·9	75 N.
70 N.	12·04	12·0	12·22	12·2	12·37	12·5	12·51	12·6	12·60	13·0	12·64	13·2	70 N.
65 N.	11·89	11·8	12·10	12·2	12·31	12·5	12·46	12·7	12·57	13·1	12·60	13·5	65 N.
60 N.	11·66	11·6	11·92	12·1	12·15	12·4	12·35	12·7	12·45	13·1	12·48	13·3	60 N.
55 N.	11·33	11·4	11·64	11·9	11·91	12·2	12·12	12·5	12·24	12·8	12·25	12·8	55 N.
50 N.	10·93	11·1	11·26	11·5	11·56	11·9	11·83	12·1	11·91	12·2	11·91	12·2	50 N.
45 N.	10·44	......	10·79	......	11·10	......	11·35	11·7	11·47	11·7	11·46	11·7	45 N.
40 N.	9·88	......	10·23	......	10·56	......	10·80	11·3	10·94	......	10·93	......	40 N.
	Long. 120° E.		Long. 130° E.		Long. 140° E.		Long. 150° E.		Long. 160° E.		Long. 170° E.		
85 N.	12·49	......	12·51	......	12·52	......	12·53	......	12·53	......	12·54	......	85 N.
80 N.	12·58	......	12·60	......	12·60	......	12·61	......	12·62	......	12·62	......	80 N.
75 N.	12·64	13·0	12·64	13·1	12·64	......	12·63	......	12·62	......	12·62	......	75 N.
70 N.	12·65	13·3	12·63	13·4	12·59	......	12·56	13·0	12·58	......	12·51	......	70 N.
65 N.	12·59	13·5	12·53	13·2	12·45	13·0	12·37	12·7	12·31	......	12·29	......	65 N.
60 N.	12·43	13·1	12·33	13·0	12·20	12·7	12·07	12·4	11·99	12·3	11·96	......	60 N.
55 N.	12·12	12·7	12·02	12·4	11·84	12·2	11·68	12·0	11·56	11·9	11·52	......	55 N.
50 N.	11·83	12·1	11·62	11·9	11·39	......	11·18	......	11·04	......	11·00	......	50 N.
45 N.	11·33	......	11·11	......	10·85	......	10·62	......	10·45	......	10·41	......	45 N.
40 N.	10·78	......	10·53	......	10·25	......	9·98	......	9·82	......	9·79	......	40 N.
	Long. 180° E.		Long. 190° E.		Long. 200° E.		Long. 210° E.		Long. 220° E.		Long. 230° E.		
85 N.	12·54	......	12·54	......	12·54	......	12·54	......	12·53	......	12·52	......	85 N.
80 N.	12·62	......	12·63	......	12·64	......	12·65	......	12·65	......	12·65	......	80 N.
75 N.	12·63	......	12·65	......	12·68	......	12·71	......	12·74	......	12·76	......	75 N.
70 N.	12·52	......	12·57	......	12·63	12·9	12·71	13·0	12·78	......	12·85	13·6	70 N.
65 N.	12·31	......	12·39	......	12·50	12·6	12·64	12·8	12·77	13·1	12·90	13·5	65 N.
60 N.	12·00	......	12·11	......	12·27	12·3	12·47	12·5	12·68	12·8	12·87	13·2	60 N.
55 N.	11·58	......	11·72	......	11·95	12·0	12·22	12·2	12·51	12·6	12·77	13·0	55 N.
50 N.	11·07	......	11·26	......	11·54	......	11·87	12·0	12·22	12·4	12·57	12·7	50 N.
45 N.	10·50	......	10·73	......	11·05	......	11·44	......	11·85	......	12·24	12·4	45 N.
40 N.	9·89	......	10·14	......	10·50	......	10·93	......	11·39	......	11·82	......	40 N.
	Long. 240° E.		Long. 250° E.		Long. 260° E.		Long. 270° E.		Long. 280° E.		Long. 290° E.		
85 N.	12·51	......	12·47	......	12·46	......	12·43	......	12·39	......	12·36	......	85 N.
80 N.	12·63	......	12·60	......	12·57	......	12·52	......	12·45	......	12·37	12·5	80 N.
75 N.	12·75	13·0	12·75	12·3	12·71	12·4	12·63	12·7	12·54	12·7	12·43	12·6	75 N.
70 N.	12·90	13·7	12·90	......	12·87	......	12·79	13·0	12·68	13·0	12·53	12·8	70 N.
65 N.	12·99	13·8	13·04	13·7	13·02	13·6	12·95	13·5	12·82	13·4	12·67	13·0	65 N.
60 N.	13·03	13·8	13·12	14·1	13·15	14·0	13·08	13·8	12·94	13·6	12·74	13·3	60 N.
55 N.	12·98	13·5	13·13	13·9	13·19	14·3	13·15	14·1	13·02	13·8	12·81	13·4	55 N.
50 N.	12·84	13·1	13·04	13·6	13·14	......	13·14	14·2	13·02	13·9	12·82	13·4	50 N.
45 N.	12·58	12·8	12·83	......	12·97	......	13·00	13·9	12·92	13·9	12·72	13·6	45 N.
40 N.	12·20	......	12·50	......	12·68	......	12·75	......	12·70	13·6	12·53	......	40 N.
	Long. 300° E.		Long. 310° E.		Long. 320° E.		Long. 330° E.		Long. 340° E.		Long. 350° E.		
85 N.	12·33	......	12·30	......	12·26	......	12·24	......	12·22	......	12·20	......	85 N.
80 N.	12·30	......	12·22	......	12·14	......	12·07	......	12·02	......	11·98	......	80 N.
75 N.	12·31	12·2	12·17	12·2	12·04	12·0	11·92	11·7	11·83	11·6	11·76	11·6	75 N.
70 N.	12·35	12·4	12·16	12·3	11·98	11·9	11·81	11·7	11·66	11·5	11·54	11·3	70 N.
65 N.	12·42	12·6	12·18	12·4	11·93	11·9	11·70	11·6	11·50	11·3	11·33	11·0	65 N.
60 N.	12·49	12·8	12·20	12·4	11·90	11·9	11·62	11·5	11·36	11·1	11·14	10·8	60 N.
55 N.	12·53	12·9	12·22	12·4	11·87	11·9	11·54	11·4	11·21	11·0	10·94	10·7	55 N.
50 N.	12·53	12·9	12·19	12·4	11·81	11·8	11·44	11·3	11·06	10·9	10·73	10·5	50 N.
45 N.	12·45	12·9	12·10	12·3	11·71	......	11·30	......	10·89	10·8	10·50	10·3	45 N.
40 N.	12·27	......	11·93	......	11·54	......	11·11	......	10·67	......	10·23	10·0	40 N.

XXIII. *An Experimental Inquiry on the Action of Electricity on Gases.—I. On the Action of Electricity on Oxygen.* By Sir B. C. BRODIE, *Bart., F.R.S.*

Received June 6,—Read June 20, 1872.

THE following pages contain the result of a prolonged series of experiments regarding the action of electricity upon certain kinds of gaseous matter. The instrument of this inquiry, by aid of which the gases were submitted to this action, is the induction-tube of W. SIEMENS *, an admirable and simple piece of apparatus, which enables us not only thus to operate upon the gases, but also to collect the products of the experiment with a view to their estimation and analysis. This instrument renders it practicable to utilize for the purposes of chemical investigation the vast powers of the coil of RUHMKORFF, and places at our disposal a new engine of research. The results at which I have already arrived are of sufficient importance to justify the anticipation that the changes thus produced by the action of electricity upon gases will prove to be a field of inquiry not inferior in interest to the electrolysis of liquids. In this first memoir I shall treat of the action of electricity upon oxygen gas, and in a subsequent inquiry, the results of which I hope speedily to lay before the Society, it is my intention to consider the action of electricity upon carbonic acid and carbonic oxide gas.

The investigations of SCHÖNBEIN in reference to ozone throw but little light upon its nature, mainly for the reason that this chemist neglected the use of the most fundamental instruments of chemical research, and rarely even attempted any quantitative valuation of its properties; hence it is that we owe our most important knowledge upon this subject, not to SCHÖNBEIN, who made it the study of his life, but to other investigators.

In a paper published in the Archives of Electricity for 1845 †, MARIGNAC and DE LA RIVE established the important fact that ozone is produced by the action of the electric spark upon pure and dry oxygen—a point which was further and conclusively demonstrated by the investigations of FREMY and BECQUEREL in 1852 ‡, who also discovered that when electric sparks were passed through pure oxygen gas enclosed in a confined space in contact with a solution of iodide of potassium or with moistened silver, the oxygen was, after the lapse of sufficient time, totally and completely absorbed by those substances. It was thus proved that for the formation of ozone oxygen alone is required; and these investigations effectually disposed of those theories, based upon inadequate or erroneous experiments, according to which the properties conferred upon oxygen by the action of electricity were regarded as due to the formation of minute quantities of nitrous acid or peroxide of hydrogen §. At the same time MARIGNAC and DE LA RIVE

* POGGENDORFF's Ann. vol. cii. p. 120. † Vol. v. p. 5. ‡ Annales de Chimie, 3 S. vol. xxxv. p. 62.

§ WILLIAMSON, Ann. Ch. Pharm. vol. lxi. p. 13. BAUMERT, POGGEND. Ann. vol. lxxxix. p. 38.

regarded this change of properties as due not to a special substance, but to a peculiar state or condition of oxygen caused by the electric action in which its "affinities were exalted," and proposed for this reason to discard the term ozone, and to term the gas in this condition simply electrized oxygen. Indeed they do not appear to have had any suspicion of the existence of ozone as an individual chemical entity distinct from oxygen itself.

A further and most important contribution to our knowledge upon this subject was made by ANDREWS and TAIT*, who, by means of a series of delicate and well-contrived experiments, arrived at the following conclusions:—(1) That under the influence of the electric action, which they employed in the form of what is termed the "silent discharge," oxygen undergoes a contraction of volume dependent upon the time for which the gas is thus acted upon, but not transcending a certain limit, the maximum contraction in their experiments being reached when the gas had diminished by one twelfth of its original volume. (2) That when the gas thus contracted was heated to 300° C., it expanded to its former bulk. (3) That when a solution of iodide of potassium was introduced into the contracted gas, an amount of iodine was formed equivalent to the amount of oxygen which disappeared in the contraction without the occurrence of any change in the volume of the gas. (4) That the gas which had been thus operated upon by iodide of potassium did not expand when heated to 300° C.

ANDREWS and TAIT do not offer any adequate interpretation of their remarkable experiments. "To reconcile," they say, "the experimental results with the view that ozone is oxygen in an allotropic form, it is necessary to assume that its density immensely exceeds that of any known gas or vapour, being, as we have seen, according to the first and second series of experiments, from fifty to sixty times that of oxygen, and according to the third series absolutely infinite: even the former results would make it only six times less dense than the metal lithium, and would place it rather in the class of solid or liquid bodies than of gaseous"†; and without absolutely rejecting the allotropic hypothesis, they proceed to seek for the origin of ozone in the decomposition of oxygen, and endeavour to explain the phenomena from this point of view.

There is, however, an hypothesis as to the constitution of ozone which would naturally present itself to the mind of a chemist profoundly convinced of the dual nature of oxygen, and by which these results would be accounted for in a simple and probable way. This hypothesis appears to have been first publicly enunciated by ODLING in his 'Manual of Chemistry,' published in 1861, where the following passage occurs (p. 94):—"If we consider ozone to be a compound of oxygen with oxygen and the contraction to be consequent upon their combination, then if one portion of this combined or contracted oxygen were absorbed by the reagent, the other portion would be set free, and by its liberation might expand to the volume of the whole; thus, if we suppose three volumes of oxygen to be condensed by their mutual combination into two volumes, then on absorbing one third of this combined oxygen by mercury the remaining two thirds would be set

* Philosophical Transactions, 1860, p. 113.

† *Loc. cit.* p. 128.

free, and consequently expand to their normal bulk, or two volumes,

$$\overset{-}{O}\,\overset{+}{O}\,\overset{-}{O}+\overset{+}{H}g^2=\overset{+}{H}g^2\,\overset{-}{O}+\overset{+}{O}\,\overset{-}{O}.\text{"}$$

SORET * subsequently discovered that if oil of turpentine or oil of cinnamon be brought in contact with oxygen containing ozone as procured by electrolysis, a diminution occurs in the volume of the gas. SORET inferred (from his experiments) this diminution in volume to be equal in amount to twice the expansion which another portion of the same gas underwent when heated, or (what ought to be the same thing) to twice the volume of oxygen absorbed from the same gas by neutral iodide of potassium.

Although I quite agree that this is really the case, at least with the ozone procured by the action of induced electricity upon oxygen, I must be excused for saying that the experiments of SORET by no means justify the conclusion. The mean ratio of the observed diminution in volume to the oxygen absorbed by neutral iodide of potassium was in the case of the first set of five experiments 2·4, a number which cannot be considered even as an approximation to the theoretical number 2; and the similar mean of the second set of seven experiments, in which the ratio was estimated of this diminution to the expansion which the same gas underwent when heated, was 1·81, a number exhibiting a considerable divergence in the other direction from the same theoretical value†. SORET, indeed, gives a preference to these last experiments, and among these to three experiments especially, which show a closer concordance with theory; but this preference seems rather to be based on a foregone conclusion in favour of the theory than from any superiority in the experiments themselves. The truth is that no precise value at all for these contractions is really indicated by the experiments, and the errors are too great for any theory to be based upon them. These deficiencies are doubtless in no way to be attributed to any want of care or skill on the part of the experimenter, but to the unavoidable errors in the method of experiment.

About the time of the publication of SORET's experiments I was myself engaged with the same subject of inquiry, and, indeed, before the publication of these experiments had ascertained the nature of the contraction (hereafter discussed) which an electrized gas undergoes when passed through a solution of neutral hyposulphite of soda. Numerous circumstances, many beyond my control, have unfortunately interfered with the prosecution of these researches, of which, however, I at last am able to lay the results before the Society.

SECTION I.

The chief difficulties in the way of the accurate investigation of this problem have arisen from the absence of any adequate method of experiment; and I shall now proceed to describe an apparatus by which these difficulties may be obviated, and by which I have been enabled to generate and collect the electrized gas in sufficient quantities for examination, to submit successive portions of the same gas to the action of various

* Ann. Ch. Phys. (4) vol. vii. p. 113. † *Loc. cit.* pp. 116 & 117.

reagents, and to estimate the variations in volume which the gas undergoes under the influence of these reagents with facility and precision.

The oxygen employed in the following experiments was procured either by the decomposition of pure chlorate of potash or by the electrolysis of dilute sulphuric acid. In the former case the oxygen was collected in one of the sulphuric-acid gas-holders, hereafter described, and thence passed through the induction-tube. In the latter case it was passed through the induction-tube immediately from the apparatus in which it was generated. I shall describe the latter arrangement, which was employed in all but my earliest experiments, and which presents many advantages.

A drawing of the vessel in which the oxygen was generated is given in Plate LI. fig. 1: *a* is a glass vessel, similar to a small gas-jar, open at bottom; this vessel is cemented into a cell of porous earthenware, *b*, by which its aperture is closed; *c* is a ring of coke, being a section of one of the cylinders employed in BUNSEN'S carbon-battery; to this is attached a platinum wire *d*. In the interior of this glass vessel is a platinum plate, to which is attached a second wire (*e*) of the same metal passing through a stopper of caoutchouc. The whole is immersed in a glass jar containing dilute sulphuric acid, with which the vessel *a* is also partially filled. The wire *d* is connected with the zinc, and the wire *e* with the platinum terminal of a voltaic arrangement, consisting of three or four GROVE'S cells; the hydrogen passes into the external air, and the oxygen is delivered through the tube *f*, in which two bulbs (*g*) are inserted containing a solution of iodide of potassium, for the purpose of destroying the traces of ozone which would otherwise be contained in the gas and interfere with the experiment.

The oxygen delivered at *f* is then passed in a slow stream through a tube of the form delineated in figure 2, containing pure and concentrated sulphuric acid, the tube being attached at *g* by a caoutchouc junction to the tube *f*; the gas, thus deprived of moisture by the sulphuric acid, is further and completely dried before entering the induction-tube by anhydrous phosphoric acid contained in three small bulbs attached to the tube.

In figure 3 is given a drawing of the induction-tube, which is fundamentally of the kind originally devised by SIEMENS, and described by him in POGGENDORFF'S 'Annalen' in the place before referred to. The tube, however, is not, as in the arrangement of SIEMENS, coated with tinfoil, but the inner tube is filled with water, in which is placed one of the terminal wires of RUHMKORFF'S coil, while the tube itself is immersed in a vessel of water connected with the other terminal wire of the coil. The gas enters the apparatus at *h*, and passing over anhydrous phosphoric acid contained in the three bulbs *i*, traverses the narrow space *k* between the two tubes, and is there submitted to the electric action, after which the electrized gas is again passed over anhydrous phosphoric acid contained in the three bulbs *l*, and is delivered at *m*.

The gas is thus submitted to the electric action in a very dry condition, which is an essential point for the production of a considerable percentage of ozone. The amount of ozone is also affected by the temperature at which the gas is thus operated on. It is especially desirable to prevent the elevation of temperature consequent on the electric

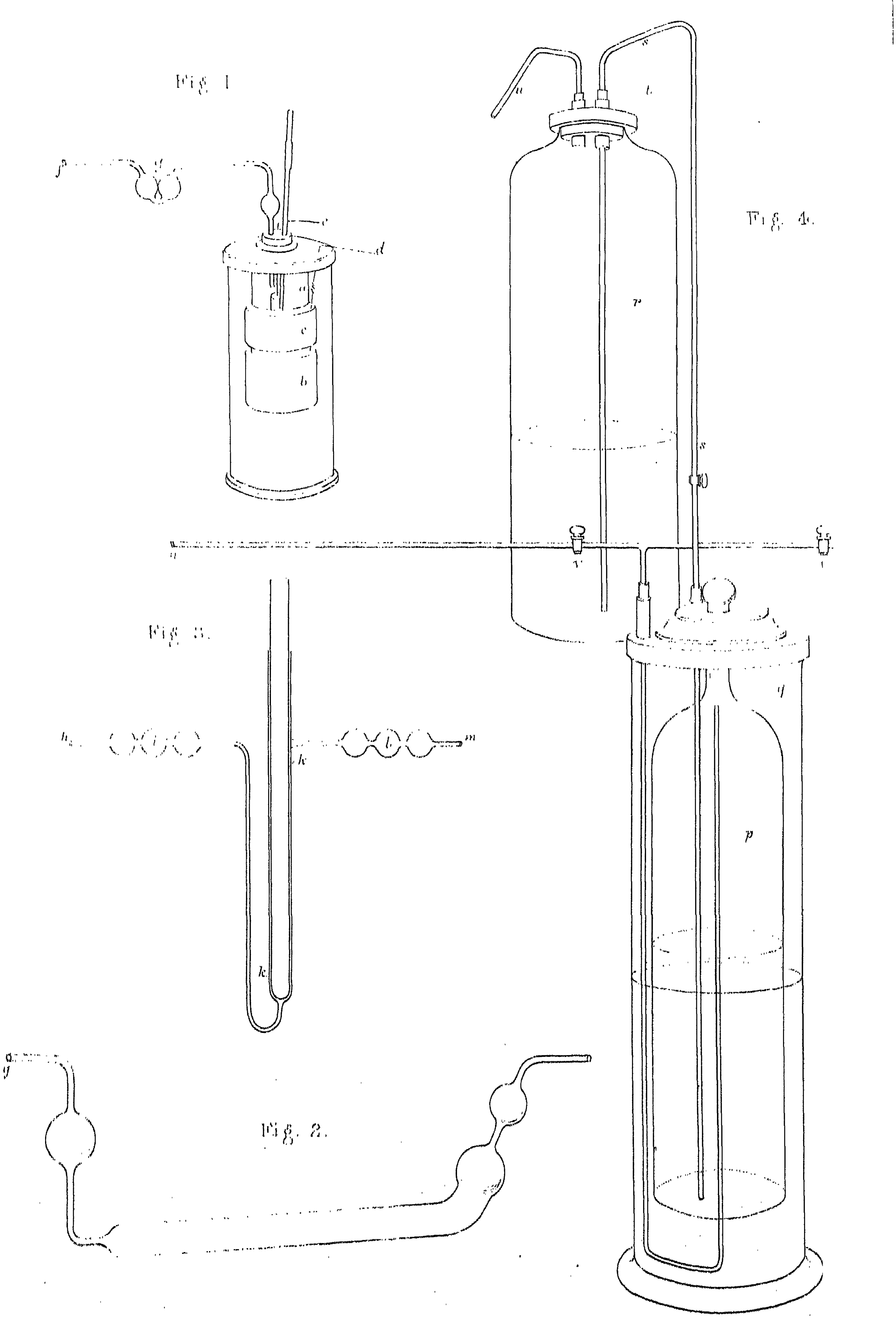


Fig. 1
Fig. 2
Fig. 3
Fig. 4
a
b
c
d
e
f
g
h
k
l
m
n
p
q
r
s
t
u
v

action, which may be done by placing fragments of ice in the interior of the tube, and also in the water contained in the external cylinder in which the induction-tube is immersed. If a lower temperature still be desired, the ice may be replaced by a mixture of ice and salt; in this latter case the precaution of filling the interior tube also with the saline solution must not be omitted. When the tube is thus cooled, either with ice or with ice and salt, the external cylinder containing the refrigerating-mixture should be wrapped in thick flannel. The temperature can readily be thus kept during a long experiment of six or eight hours' duration at 0° C., or even at $-10°$ C.

The electrized gas is collected and preserved for the purpose of experiment in a gas-holder, delineated in Plate LI. fig. 4. On this side of the induction-tube connexions of caoutchouc can no longer be employed, this substance being instantaneously corroded by even the minutest trace of ozone, and the junction between the gas-holder and the induction-tube is effected by means of what may be termed a paraffine-joint. Over the tubes to be connected, which are placed close together, is slipped a piece of glass tube into which they exactly fit, and from which they are separated by a capillary space; a fragment of pure paraffine is placed at the external junction of the tubes; the union of the tubes is effected by gently melting the paraffine; the liquid paraffine is extremely limpid, and runs into and fills up the narrow space between the tubes. When the paraffine is solidified, the tubes are united by a joint, which is perfectly air-tight, which will resist very considerable pressure, and which is quite unaffected by the passage of the ozone. This simple joint is an essential feature of this arrangement, and would doubtless be of great service in many forms of gas-apparatus.

The gas-holder consists of a glass bell (*p*) contained in a glass cylinder (*q*), in which it is suspended, being supported by a knob of glass passing through a wooden cap fitted to the top of the jar; this cap is made in two pieces, which are subsequently united so as to be readily placed in a proper position as a support to the glass bell. The wooden cap was coated internally with paraffine, to protect it from the effects of accidental contact with the acid. It would, however, be far better to make the cap of glass, which could easily be done.

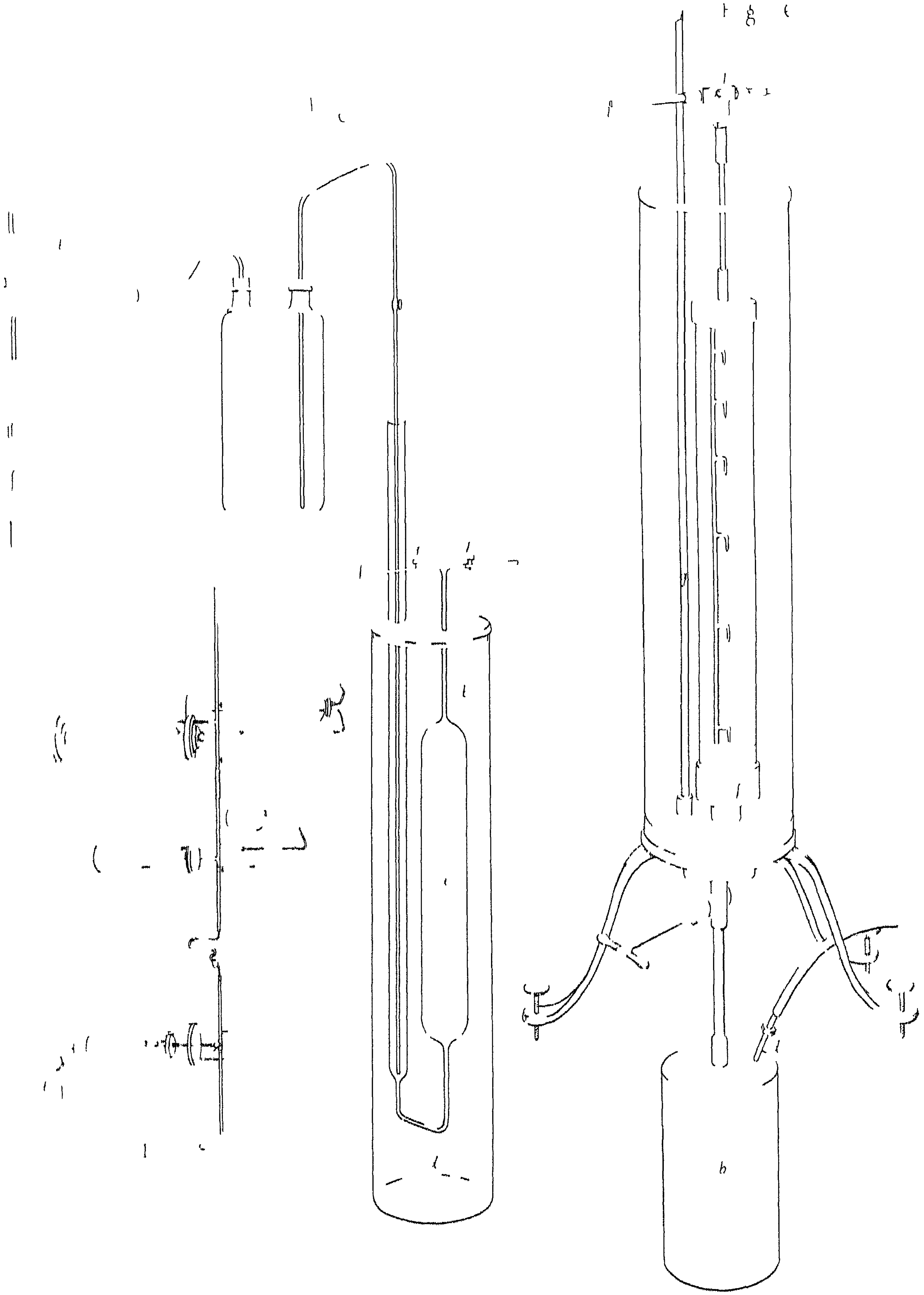
At a superior level is placed a glass jar (*r*) containing pure and concentrated sulphuric acid; this jar is connected by a siphon-tube, *s* (in which is placed a glass stopcock), with the lower cylinder, *q*. This upper jar, which I shall term the reservoir, is closed by a wooden cap, *t*, which also would be better made of glass, through which the siphon-tube passes, and in which is also fitted a second glass tube, *u*. The gas from the induction-tube is delivered at *n*, whence it passes into the gas-holder by an arrangement of tubes, which is best understood from the drawing.

I will now describe the way in which the apparatus is worked. A quantity of concentrated sulphuric acid, just sufficient to fill the glass bell (*p*) and the external cylinder (*q*) to the top of the bell, is placed in the reservoir *r*, the siphon-tube being filled with the same. The stopcock at *v* is closed, and the stopcock *w* open; the glass stopcock in the siphon-tube (*s*) is now opened, the air is expelled from the glass bell (*p*), which is

thus filled with sulphuric acid. The stopcock in the siphon-tube is now closed, as also the stopcock w; the stopcock v is opened, and the gas as delivered from the induction-tube at n is allowed to pass into the gas-holder. The sulphuric acid which is thus displaced is drawn back into the reservoir r, by creating in the reservoir a partial vacuum; this is effected by means of an air-pump, connected with the glass tube u by a caoutchouc tube. Similarly, any required quantity of gas may be delivered from the gas-holder by closing the stopcock v and opening the stopcock w, the gas being expelled from the gas-holder by the column of sulphuric acid in the jar delivered from the siphon-tube.

The drawing of the apparatus given in the figure is a quarter the actual height; the capacity of this gas-holder is about 3000 cub. centims. The arrangement, although somewhat complicated in description, is easily worked.

The volume of gas submitted to experiment was measured in a glass pipette, of which a drawing is given in Plate LII. fig. 5 to the same scale as the last. The capacity of the pipette between the two marks b and c was estimated by calibration with mercury, the quantity of mercury required to fill the pipette between the marks being weighed at an observed temperature; its capacity as thus ascertained was 290·8 cub. centims. It was then welded to a glass tube of the form given in the figure: e is a reservoir of sulphuric acid with a siphon-tube attached, similar in principle to that previously described; d is a cylinder containing water, in which the gas-pipette a is immersed, and of which the temperature is observed by means of a thermometer placed in it. The gas-pipette is placed in connexion with the gas-holder by means of a paraffine-joint at f; the arrangements for working this pipette are precisely similar to those previously described in the case of the gas-holder. At the commencement of the experiment the pipette is filled with sulphuric acid from the reservoir e by means of the siphon-tube, the stopcock g being closed and h open; this having been effected, the pipette is filled with the electrized gas by closing the stopcock h and opening the stopcock g, a partial vacuum being made in the reservoir e as previously described, and a pressure of 2 or 3 inches of sulphuric acid being put upon the gas in the gas-holder. The pipette is thus filled with gas to some point below the mark c; the stopcock g is then momentarily lifted so as to allow the sulphuric acid to rise to the mark c. The quantity of sulphuric acid in the reservoir was so adjusted that when the siphon-tube was empty the pipette was necessarily filled to this level. It is to be observed that the tubes connected with the apparatus were first filled with the electrized gas by drawing over, at the commencement of the experiment, a certain volume of the gas into the pipette and expelling it into the air. In this manner the pipette was filled to the mark c with the electrized gas at atmospheric pressure as observed by the barometer, and at the temperature indicated by the thermometer placed in the water in which the pipette was immersed; the gas was delivered from the pipette at c. To effect this the stopcock in the siphon-tube was opened, and a pressure was thus put upon the gas, the stopcock h being also open and the stopcock g closed: the quantity of sulphuric acid was so arranged that the gas could readily be brought at atmospheric pressure to the



mark *b*; the capacity of the pipette having been determined between these points, a definite volume of gas at a known temperature and pressure was thus delivered at the exit-tube *i*. Evidence of the extreme accuracy of this method of measurement will shortly be given. It is, so far as I am aware, the first application to the estimation of the volume of gases of those principles of pipette-measurement which have been of such good service to the chemist in the case of the measurement of liquids.

In order to estimate the changes in bulk which the electrized gas underwent in the various experiments hereafter described, the measuring-apparatus was employed of which a drawing is given in Plate LII. fig. 6. In this apparatus, which I shall term the aspirator, the volume of gas at 0° C. and 760 millims. pressure is ascertained by determining the pressure which it is necessary to put upon the gas in order to cause it to occupy a known space at a known temperature. This is the principle of REGNAULT's apparatus for gas-analysis, and also of FRANKLAND's apparatus.

The apparatus consists of a cylinder of strong glass (*a*), connected by an iron tube with an iron reservoir (*b*), containing an amount of mercury rather more than sufficient to fill the cylinder *a*. In the iron tube connecting the cylinder and the reservoir is intercalated a stopcock (*c*), by which the connexion between the cylinder and reservoir may at pleasure be made or cut off. In the reservoir *b* a small iron tube (*d*) is inserted, connected by a tube of caoutchouc with a forcing-pump firmly fixed to the table on which the apparatus is placed. By means of this forcing-pump the air contained in the upper part of the reservoir may be compressed, and any required pressure put upon the mercury contained in it. The cylinder *a* is cemented, by means of a resinous cement, into two steel caps (*e* and *f*); the lower cap (*f*) is screwed firmly upon the support of the apparatus, which is made of iron. The cylinder is connected, by means of a channel cut in the lower part of the steel cap (*f*) and continued through the iron frame, with a glass tube (*g*), which is about half an inch in diameter and graduated in millimetres: this tube I shall speak of as the pressure-tube. The cylinder *a* and the pressure-tube *g* are thus in permanent connexion, and constitute one vessel, which is broken into parts solely for facility of construction. This apparatus is supported upon three screws, as shown in the figure, by the adjustment of which the pressure-tube *g* is placed in a perpendicular position before the commencement of the experiment. A piece of strong glass tubing, of fine bore, is cemented into a steel socket which forms part of the steel cap *e*, the upper end of the same glass tube being similarly cemented into a steel socket (*h*), on the upper part of which a screw is cut by which it is connected with a steel stopcock (*k*). Two steel sockets, similar to the socket *h*, are screwed into the stopcock (*k*) and two glass tubes (*l* and *m*) are cemented into these sockets; the steel stopcock *k* is what is termed a three-way stopcock, in which the channels are so cut that a communication may be made between the tube *l* and the cylinder *a*, or between the tube *m* and the cylinder *a*, or between the tubes *l* and *m* (all other communications being shut off), at pleasure, or the communications may be entirely closed.

In the cylinder *a* is placed a thin piece of glass rod, to which seven points are

attached, also of glass, as shown in the figure, the points being finely ground. This glass rod is attached to the sides of the tube by a little resinous cement. The rod may be thus fixed after the cylinder *a* has been cemented into the lower cap *f*. The capacity of the cylinder *a*, between each point, is ascertained by calibration with mercury, which is effected before the reservoir is attached to the apparatus. In order to calibrate the cylinder *a*, the stopcock *c* is closed and *k* opened to the air; the cylinder *a* is then filled with mercury (which has been carefully purified, and of which the specific gravity has been determined by experiment) up to the stopcock *k*. The mercury is then run out of the apparatus by means of the stopcock *c* to a level a little below the first point, 1; the stopcock *c* being again closed, a portion of the same mercury, exactly sufficient to bring the level of the mercury to the point 1, is poured back into the apparatus by means of the pressure-tube, the level of the mercury is read on the pressure-tube, and the mercury which has been run out of the apparatus is weighed. From these data the capacity of the cylinder *a*, taken together with the capacity of the pressure-tube *g* from the stopcock *k* to the first point 1, may be calculated. By perfectly similar operations the capacity of the cylinder and pressure-tube at the other points (2, 3, 4, 5, 6, 7) may be ascertained, and the heights of those points upon the pressure-tube *g* determined. In order finally to determine the capacity of the cylinder *a* at the various points, we have to deduct from the capacity of the cylinder and pressure-tube at those points as thus ascertained the capacity of the pressure-tube. This capacity is readily determined by filling the apparatus as before with mercury, closing the stopcock *k*, and running the mercury out, by opening the stopcock *c* (the vessel *b* being detached), from successive portions of the pressure-tube alone, care being taken to run out so much as to pour back in each case a little mercury in order to secure the right reading of the meniscus; this mercury is then weighed. The pressure-tube being graduated in millimetres, a simple calculation informs us of its capacity at any desired interval. Deducting the capacity of the pressure-tube from the capacity of the cylinder and pressure-tube as previously determined, or, rather, deducting the weight of the mercury at a known temperature and of a known density corresponding to the capacity of the pressure-tube from the weight of mercury corresponding to the capacity of the cylinder and pressure-tube, we arrive at the capacity of the cylinder at any desired point.

The cylinder and pressure-tube are enclosed in a second glass cylinder (*n*), which is fastened into an iron ring, by means of which it is attached to the frame of the apparatus; this cylinder is filled with water, in which a thermometer is placed.

The apparatus thus put together is to be carefully examined to ascertain that there is no leakage in the various joints and stopcocks; with this view the reservoir of mercury having been now attached to the apparatus, the stopcock *k* is opened and the cylinder *a* is partially filled with mercury; the stopcock *k* is closed, the stopcock *c* opened, and a considerable pressure put upon the gas by means of the forcing-pump before referred to; the stopcock *c* is then closed, and the height of the mercury in the pressure-tube read: the level of the mercury in the pressure-tube should not appreciably vary for several hours.

In order to determine the volume of a gas enclosed in the cylinder a, the gas must be first expanded, if necessary, below the point at which the reading is to be made; this is effected by opening the stopcock c, the communications being open between the reservoir b and the external air; the stopcock c is then closed, and the pressure put upon the mercury in the reservoir by means of the forcing-pump; the stopcock c is then partially and carefully opened so as to allow the mercury very slowly to rise until it is brought to the level of the point; the stopcock is instantaneously closed, and the level of the mercury on the pressure-tube read: the temperature of the water in the external cylinder is given by means of the thermometer placed in it; the barometer is also read, and from these data, the capacity of the cylinder at the point at which the observation is made being known, the volume of the gas at 0° C. and 760 millims. pressure may be calculated.

With a view of testing the accuracy of this method of measurement, the ratio of the pressure under which the same volume of air exists at two adjacent points was determined throughout the apparatus, and these ratios were compared with the ratios of the capacities of the same two adjacent points as determined by mercurial calibration; the numbers should be the same in both cases; thus, putting $p_1, p_2, p_3, \ldots$ as the pressures under which any volume of air exists at the points 1, 2, 3, ..., and $v_1, v_2, v_3, \ldots$ as the capacities of the apparatus at the same points, as determined by mercurial calibration, the following results were obtained. The ratios of the pressures given below are in each case the mean of not less than three experiments; the several observations at two adjacent points were made with slightly varying volumes of air, so as to get different readings on the pressure tube in each case.

$$\frac{p_1}{p_2}=2\cdot0597, \qquad \frac{v_2}{v_1}=2\cdot0576,$$

$$\frac{p_2}{p_3}=1\cdot6534, \qquad \frac{v_3}{v_2}=1\cdot6541,$$

$$\frac{p_3}{p_4}=1\cdot4464, \qquad \frac{v_4}{v_3}=1\cdot4462,$$

$$\frac{p_4}{p_5}=1\cdot3989, \qquad \frac{v_5}{v_4}=1\cdot3990,$$

$$\frac{p_5}{p_6}=1\cdot4685, \qquad \frac{v_6}{v_5}=1\cdot4696.$$

Now the capacity of the aspirator at the fifth point may also be determined by drawing over into the aspirator a pipette of air, and ascertaining the pressure at which that volume of air exists at that point; assuming this to be the true capacity of the aspirator at that point, and applying the ratios of pressures to the numbers thus obtained for that capacity, the following numbers are arrived at:—

$$\frac{72{\cdot}000}{2{\cdot}0597}=34{\cdot}957 \text{ capacity in cub. centims. at point } 1,$$

$$\frac{119{\cdot}04}{1{\cdot}6534}=72{\cdot}000 \quad ,, \quad ,, \quad ,, \quad ,, \quad ,, \quad ,, \quad 2,$$

$$\frac{172{\cdot}19}{1{\cdot}4464}=119{\cdot}04 \quad ,, \quad ,, \quad ,, \quad ,, \quad ,, \quad ,, \quad 3,$$

$$\frac{240{\cdot}89}{1{\cdot}3989}=172{\cdot}19 \quad ,, \quad ,, \quad ,, \quad ,, \quad ,, \quad ,, \quad 4,$$

$$240{\cdot}89\times1{\cdot}4685=353{\cdot}75 \quad ,, \quad ,, \quad ,, \quad ,, \quad ,, \quad ,, \quad 6,$$

the capacity at point 5, as determined from the pipette, being 240·89 cub. centims. This method of determining the capacity of the aspirator may be termed the method of air calibration.

The capacity of the apparatus at the different points, as determined by the respective methods of mercurial calibration and air calibration, are given in the following Table:—

	By mercurial calibration.	By air calibration.
Capacity in cub. centims. at point 1 . . .	34·93	34·96
,, ,, ,, ,, ,, ,, 2 . . .	71·87	72·00
,, ,, ,, ,, ,, ,, 3 . . .	118·88	119·04
,, ,, ,, ,, ,, ,, 4 . . .	171·92	172·19
,, ,, ,, ,, ,, ,, 5 . . .	240·51	240·89
,, ,, ,, ,, ,, ,, 6 . . .	353·45	353·75

The capacities respectively given in these two columns are determined by independent methods; and it must be admitted, if we consider the numerous observations necessary for any one determination, that the concurrence of these numbers is truly surprising, and affords a sufficient guarantee of the accuracy of the method employed for the determination of the volumes of gases in these experiments. It is necessary, however, to observe that the previous description is exactly applicable only to the ultimate form which this apparatus assumed with the various modifications suggested by use. In my earlier experiments the apparatus employed differed in various details from that just described; it was, however, constructed on perfectly similar principles—namely, the measurement of a determinate volume of gas by means of a pipette, and the estimation of the volumes of gases at 0° C. and 760 millims. from the observation of the pressure and temperature at which the same gases occupy a known space. It does not appear to me necessary to trouble the reader with a description of this apparatus, which differed from that just described rather in regard to convenience than precision, the difference in this latter respect, if any, being in no way sufficient to affect the general result.

The pipette was placed on a table, being separated from the aspirator by an interval of about 8 or 10 inches; in this interval the experiment to which the electrized gas was submitted was made. When the gas was passed through a liquid, small glass bulbs were employed of the kind delineated in Plate LII. fig. 7. In bulb *a* the gas is delivered through a capillary tube so as to pass in minute bubbles. It is hardly necessary to observe that the level of the liquid in the bulb was so adjusted at the com-

mencement of the experiment, by drawing a few bubbles of air through it by means of the aspirator, as to occupy the same position as that in which it was finally left at the conclusion of the experiment. Before the commencement of the experiment the aspirator was completely filled with mercury from the reservoir.

In Plate LII. fig. 8 a drawing is given of the whole apparatus as arranged for experiment.

I may here express the obligations which I am under to my assistant, Mr. J. ROBINSON, for the effectual way in which he has aided me in this investigation, especially in the construction and use of this apparatus for measuring gases, towards the completion and perfecting of which he contributed several valuable suggestions.

SECTION II.

The action of ozone upon iodide of potassium has been investigated by ANDREWS and TAIT*, and also by VON BABO and CLAUS†. These experiments were made in both instances with great care; and my own observations entirely confirm the conclusions at which these chemists arrived, and so far present no new feature. It is, however, very desirable in so obscure a subject to multiply experiments; and as the following experiments were conducted in a totally different manner to that in which these chemists operated, and illustrate the working of the apparatus and the degree of precision attained by it, I shall lay them before the reader.

A known volume of the electrized gas was drawn over from the gas-holder into the pipette and there measured. The gas was then passed through a solution of iodide of potassium contained in one of the glass bulbs previously referred to into the aspirator, where the volume was again measured. After the experiment the solution of iodide of potassium was rendered acid by means of a dilute solution of hydrochloric acid, and the iodine formed estimated by a standard solution of hyposulphite of soda. The quantity of oxygen equivalent to this iodine is here termed the "Titre" or "Iodine-titre" of the gas; it is a quantity which for the same gas is constant, and which may be estimated with the greatest precision: I have therefore selected this quantity as the unit with which other analogous quantities are compared.

It is to be observed that ozone is by no means the unstable thing which it is generally imagined to be. The concentrated sulphuric acid over which ozone has been long kept becomes singularly free from colour and of a peculiar brightness. This doubtless arises from the oxidation by the ozone of the particles of organic matter otherwise invariably present in it; but when the sulphuric acid has attained this condition, the electrized gas may be kept over it for many hours at the temperature of the laboratory without appreciable alteration of the "titre." Thus in an experiment not made for this purpose, and made without any special precautions for the preservation of the gas, the "titre" of a gas, twenty-four hours after the gas had been submitted to the electric action, was equivalent to 28·25 cub. centims. of hyposulphite of soda; after sixty-six hours the

* Philosophical Transactions, 1860, p. 113.

† Annalen der Chemie und Pharmacie, Supplementband ii. (1863), p. 297.

"titre" had sunk to 23 cub. centims., after ninety hours to 20 cub. centims., and after 114 hours to 18·75 cub. centims.; and it is highly probable that the electrized gas might be preserved over perfectly pure sulphuric acid in a cool place with very slight and gradual alteration. In the present experiments, however, no error could arise from such alteration of the gas, as the "titre" of the gas was invariably taken immediately before any series of experiments was made; and if the experiments were extended over a time in which, judging from previous experience, the "titre" of the gas might be altered, this "titre" was again taken at the conclusion of the experiments. The "titre" is quite independent of the strength of the solution of iodide of potassium employed; it is not, however, desirable to operate with a strong solution, as in this case errors may arise from the oxidation of hydriodic acid during the process of titration by means of atmospheric oxygen.

In the following Table the results of eight experiments are given, in which the volumes of the electrized gas before and after passing through a solution of iodide of potassium are compared, the volume before being that read in the pipette, the volume after being that read in the aspirator; these volumes, and all other similar volumes referred to in these experiments, are given in cubic centimetres reduced to 0° C. and 760 millims. pressure. In the first column I have given the "titre" of the quantity of gas employed in cubic centimetres of oxygen similarly reduced.

"Titre."	Volume before the experiment.	Volume after the experiment.
13·58	269·55	269·57
7·53	271·33	271·32
10·52	276·68	276·11
5·82	272·28	271·89
5·47	271·46	271·46
13·17	274·18	273·84
13·17	273·87	273·45
13·17	273·90	274·00
Mean 10·30	Mean 272·906	Mean 272·705

Assuming the mean as the correct result, it appears that for every 100 cub. centims. of gas in the pipette 99·93 cub. centims. appear in the aspirator, and 3·77 cub. centims. of oxygen are absorbed by the iodide of potassium without any appreciable diminution of the volume of the gas, the slight difference found in the mean value of the volumes before and after the experiment being fully accounted for by the absorption by the alkaline liquid of minute quantities of oxygen.

[To increase the percentage of ozone was, for the purpose of the present experiments, no great object; indeed to a certain extent it was even disadvantageous, as a gas rich in ozone is more readily subject to decomposition than a gas containing a smaller proportion. The average amount of ozone in the gas as actually employed in these experiments was about 4 per cent., but occasionally much higher. The following Table contains the record of a few estimations of ozone in the gas after collection in the gas-holder.

Volume of gas at 0° and 760 millims.	"Titre" in cub. centims. at 0° and 960 millims.	"Titre" on 100 volumes of gas.
86·97	4·28	4·92
269·5	13·58	5·04
281·7	14·29	5·07
272·8	15·15	5·55
270·9	14·74	5·44

The actual "titre" of the gas issuing from the induction-tube must, however, in all cases have been somewhat higher than that here given, since several hours were occupied in the collection of the gas, during which time the "titre" was constantly although slowly diminishing. In the last experiment in the Table "the titre" of the gas was not taken until the day after that on which it was prepared, and must, judging from the usual rate of decomposition of the ozone, originally have amounted to at least 6·5 per cent.

The experiments recorded in the following Table were differently conducted, the "titre" of the gas being taken immediately after its exit from the induction-tube The temperature of the experiment is given in the first column.

Temp.	Volume of gas at 0° and 760 millims.	"Titre" in cub. centims. at 0° and 760 millims.	"Titre" on 100 volumes of gas.
0°	88·97	5·27	5·93
−12°	88·97	5·65	6·35
− 9°	88·15	5·71	6·47
−10°	88·15	5·75	6·52

A very powerful coil was employed in these experiments. The passage of the gas in each experiment occupied about thirty minutes. The greatest contraction and highest titre attained in the experiments of Von Babo and Claus was 5·74 per cent.*; but this was reached in only one instance, and the results of their other experiments were far below this amount.

The following experiment was made with the view of ascertaining the effect of the repeated electrization of the gas by passing it several times through the induction-tube. The induction-tube was placed between two of the sulphuric-acid gas-holders previously described, so that the gas operated upon could be drawn through it from the one to the other, by causing a difference of pressure in the gas-holders, and thus submitted to the electric action as often as might be desired. After the passage of the gas through the induction-tube, portions of it were at intervals drawn off into the gas-pipette, and the ozone estimated as usual by iodide of potassium.

A portion of oxygen was thus passed once through the induction-tube and there submitted to the action of the electricity generated by a powerful coil worked by means of five elements of Grove's battery of the usual size.

A pipette of 94 cub. centims. capacity was filled with the gas at barometric pressure and a temperature of 16° C., and the ozone estimated by passing it through iodide of potassium.

* *Loc. cit.* p 303.

The iodine formed required for titration 28 cub. centims. of the standard solution of hyposulphite, of which 1 cub. centim. was equivalent to 0·1082 cub. centim. of oxygen. This corresponded to a "titre" of about 3·4 per cent. of oxygen.

The gas was again passed three times through the induction-tube and the ozone again estimated, the volume of gas, temperature, and pressure being the same as in the previous experiment. 28 cub. centims. of hyposulphite were again required for the titration.

The gas was now passed five times through the induction-tube, but a comparatively small coil was used in the experiment with five of GROVE'S cells. The same volume as before required for titration 27 cub. centims. of hyposulphite; that is to say, the "titre" of the gas, after having been passed ten times through the induction-tube, was almost, if not quite, the same as the titre of the same gas which had been passed once through the induction-tube.

The gas from the last experiment was again titred after an interval of sixteen hours, during which time the quantity of ozone was materially diminished. The same volume as before now required for titration 17·5 cub. centims. of hyposulphite. The gas was now passed twice through the induction-tube, the same coil being employed as in the last experiment. The same volume of gas as before now required for titration 29 cub. centims. of hyposulphite.

The gas was again passed twice through the induction-tube. The same volume as before required for titration 29·5 cub. centims. of hyposulphite.

It thus appears that there is a fixed limit prescribed by the conditions of the experiment beyond which the formation of the ozone cannot pass, and, moreover, that this limit is reached at once.

In this last respect these results differ essentially from those of VON BABO and CLAUS*, who found that for the production of a high percentage, 3·1 to 5·7 per cent. of ozone, the gas required to be submitted for many hours to the action of the electricity generated by a powerful coil, and that for several hours the gas thus operated upon underwent a regular diminution in volume. A point, however, was ultimately reached at which the volume of the gas remained unaltered.

No difference was detected, by detonation with hydrogen, between the composition of the gas previous to the experiment and its composition after having been submitted in the induction-tube to the electric action and passed through the solution of iodide of potassium. In the following experiment a bulb containing a solution of iodide of potassium was attached to the induction-tube, through which a current of oxygen, prepared by electrolysis and dried by anhydrous phosphoric acid, was passed direct from the generator. The current of oxygen was passed through the tube and solution for from four to five hours before turning on the coil, and a portion collected and detonated with hydrogen. The numbers thus obtained corresponded to 100·06 per cent. of oxygen. The coil was then set to work without disturbing the apparatus, and after half an hour a portion of the gas was again collected and analyzed: it was found to contain 99·1 per cent. of oxygen.

* *Loc. cit.* p. 304.

In another similar experiment the gas was analyzed in the first instance, after having been submitted to the electric action and passed through the solution of iodide of potassium, and was found by detonation with hydrogen, in two determinations respectively, to contain 99·5 and 99·0 per cent. of oxygen. The action of the coil was stopped, the passage of the current of oxygen continued for an hour, and the gas was again collected and analyzed; it was found to contain 99 per cent. of oxygen.

The experiments of which the results are given in the Table below were instituted with the view of effecting a comparison between the amount of oxygen corresponding to the "titre" of the gas and the increment of weight of the solution of iodide of potassium through which the electrized gas was passed.

The general arrangements were the same as in the experiments last described. A current of pure and dry oxygen was passed direct from the generator through the induction-tube, where it was submitted to the electric action; thence it was passed through a tube containing anhydrous phosphoric acid into the bulb containing the solution of iodide of potassium; to this a second tube, containing anhydrous phosphoric acid, was attached, which was weighed, together with the bulb containing the solution of iodide, before and after the experiment, the exit of the gas being through a fine capillary tube. At the commencement of the experiment a current of oxygen was passed through the apparatus until the weight of the bulb of iodide of potassium and the desiccating tube attached to it became constant; they were similarly weighed after the experiment, the difference of weight in the two cases being the increment of weight due to the passage of the electrized gas.

In column I. this increment of weight is given, W; in column II. the corresponding "titre" (that is to say, the weight of oxygen corresponding to the iodine found), T; in column III. the difference of these two, W—T; in column IV. the increment of weight corresponding to 100 parts of oxygen as estimated by titration, that is $100\times\frac{W}{T}$.

I. W.	II. T.	III. W—T.	IV. $100\times\frac{W}{T}$.
grm.	grm.	grm.	
·0719	·0689	·003	104·3
·1932	·1865	·0067	103·5
·1602	·1548	·0054	103·4
·3338	·3245	·011	103·2
·3939	·3836	·0103	102·7
			103·4=Mean.

The strength of the solution of iodide of potassium was intentionally varied in the last two experiments—the last experiment being made with a very weak solution of iodide of potassium containing 2 grammes of iodide in 25 cub. centims. of water, the preceding experiment with a relatively very strong solution. It hence appears that for every 100 parts of oxygen shown by the "titre" of the solution 103·4 parts of matter

are absorbed by that solution. The value of the hyposulphite employed for the titration was estimated with the greatest care; and the difference of these two numbers certainly does not depend on any error in the mode of conducting the experiment. Moreover every chemist who has experimented upon this subject has observed a difference in the same direction. The question is as to the cause of this difference.

It appears, on the face of the results given in the preceding Table, that this difference is proportional, or nearly proportional, to the "iodine-titre," which, again, is itself proportional to the quantity of oxygen employed in the experiment.

It was ascertained by ANDREWS *, and the point has been amply confirmed by MEISSNER, that when the electrized oxygen is passed through an acid solution of iodide of potassium this discrepancy no longer exists, but the increment of weight agrees with the "titre." The same is true when the gas is passed through the solution of neutral iodide until the passage of the ozone is no longer arrested by it, in which case the whole of the iodine is converted into the form of iodic acid †. Two causes may be indicated, both of which tend to create such a discrepancy:—(1) the solution of oxygen in the alkaline solution of iodide of potassium; (2) the formation of oxides of nitrogen in the induction-tube from traces of atmospheric air mixed with the oxygen employed in the experiment. I have ascertained by direct experiment that when atmospheric air, carefully dried, is submitted in the induction-tube to the electric action, very considerable quantities of the oxides of nitrogen are formed. Thus in one experiment in which 2900 cub. centims. of air were thus operated upon, and then passed through a bulb containing a solution of caustic potash, 0·0086 gramme of nitrogen was after the experiment detected in the alkaline solution in the form of nitric and nitrous acids, the nitrogen being carefully estimated in the form of ammonia. Now, assuming the iodine-titre to have amounted in the previous experiments to 4 per cent. of the total gas, in the first experiment (which exhibits the greatest divergence) 1257 cub. centims. of oxygen must have been operated on in the induction-tube. If the gas contained only 1 vol. in 1000 of nitrogen, 1000 cub. centims. would contain 0·00125 gramme of nitrogen, corresponding to ·0034 gramme of the teroxide of nitrogen, which is more than the whole difference.

ANDREWS attributes the discrepancy referred to to the presence of carbonic acid in oxygen formed by electrolysis ‡; but, as has been clearly shown by BAUMERT §, the occurrence of carbonic acid was simply a peculiarity in the experiments of ANDREWS, and, moreover, the gas employed by MEISSNER was derived from chlorate of potash, and specially freed from carbonic acid ||. In the case of gas collected, as in the present experiments, over large quantities of sulphuric acid, such traces as might be present, either of the oxides of nitrogen or of carbonic acid, would doubtless be removed by solution in that liquid.

There is still something here to be explained; but I have not pursued the subject

* Philosophical Transactions, 1856, vol. cxlvi. p. 8.

† MEISSNER, p. 78, Table B.

‡ Philosophical Transactions, 1856, vol. cxlvi. p. 4.

§ Annalen der Physik, vol. xcix. p. 91.

|| MEISSNER, p. 17.

further, any errors arising from this cause being too minute for satisfactory appreciation by the methods employed, and not essentially affecting the results.—April 1873.]

In the following experiments a pipette of electrized gas was passed through a small glass tube heated with a Bunsen burner, and the volume measured in the aspirator. In experiment 1 a pipette of gas was also passed through a solution of iodide of potassium, and the volume measured with the result given in the first line in the Table below. In column 4 the sum of the volume in the pipette and the "titre" of the gas is given.

	"Titre."	Volume before the experiment.	Volume after the experiment.	Sum of the "Titre" and the volume of the gas before the experiment.
Experiment 1 ...	12·27	270·53	270·49	———
	12·27	270·07	282·55	282·34
*Experiment 2 ...	12·27	290·81	303·24	303·08

This result is in perfect concordance with the experiments of Von BABO and CLAUS†, who found, in the series of experiments before referred to, that the contraction which oxygen underwent under the influence of electricity was equal to the volume of oxygen represented by the titre of the gas, the mean of their experiments giving a contraction of 98·27 volumes for every 100 volumes estimated by titration. The experiments also of ANDREWS and TAIT indicate the same conclusion, their last and most concordant and exact series of experiments giving (if I rightly understand them) a contraction of 93 to 95 volumes for every 100 volumes of oxygen thus estimated‡.

It was a matter of interest to ascertain the way in which the ozone is affected by heat, and the amount of ozone capable of surviving at different temperatures. In the three following experiments a pipette of the electrized gas was passed first through a glass tube heated in a bath of definite and constant temperature, and then through a solution of iodide of potassium, the gas being finally measured in the aspirator; the difference between the original "titre" of the gas and the "titre" after its passage through the heated tube gives the amount of ozone destroyed, which should correspond with the increment of volume as ascertained by measurement in the aspirator.

In the first column of the following Table is given the temperature at which the experiment was made; in column II. is given the "titre" of the gas before the experiment, T; in column III. the volume before the experiment, V; in column IV. the "titre" of the gas after its passage through the heated tube, T_1; in column V. the sum of the "titre" before the experiment, and the volume before the experiment, $T+V$; in column VI. the sum of the "titre" after the experiment, and the volume after the expe-

* Although the "titre" of the gas happens to be the same in these two experiments, they were made with different gases at different times.

† Annalen der Chem. u. Pharm., Supplementband ii. p. 303.

‡ Philosophical Transactions, 1860, vol. cl. p. 123.

riment, V_1, that is, T_1+V_1; in column VII. is given the difference of the "titre" before the experiment and the "titre" after the experiment, $T-T_1$; and in column VIII. the percentage of ozone destroyed as calculated from the equation, $x=100\frac{T-T_1}{T}$, where x is the percentage referred to, and T and $T-T_1$ are the numbers belonging to the experiment in columns II. and VII.

I. Temperature.	II. T.	III. V.	IV. T_1.	V. $T+V$.	VI. T_1+V_1.		$100\frac{T-T_1}{T}$.
110° C.	14·48	273·64	13·63	288·12	286·21	0·85	5·87
150° C.	14·43	272·96	11·59	287·39	287·08	2·84	19·68
200° C.	14·43	273·50	0·41	287·93	287·08	14·02	97·15

If the experiments were made with perfect accuracy, the numbers in columns V. and VI. should be identical. In the first experiment the difference between these numbers is beyond the usual error of experiment. This, however, does not affect the "titre" of the gas, which is quite independent of any accidental error of measurement. It thus appears that by merely passing the electrized gas through a tube heated to 200° C. 97·15 per cent. of the ozone is destroyed. 270° C. is the temperature given by ANDREWS and TAIT as that at which the ozone is "rapidly destroyed;" the point of rapid decomposition of the ozone lies, however, considerably below this temperature.

The change in volume which the electrized gas undergoes when brought in contact with metallic silver and certain other substances is closely related to the expansion of the gas at an elevated temperature; I have made some experiments on this point also.

When the perfectly dry electrized gas is passed through a tube containing silver leaf, the silver leaf becomes dark in colour at the place where the gas enters the tube, the change in colour appearing as dark specks and also as a transparent film of a purple hue on the surface of the silver. This change in appearance extends, however, but a very little way into the tube, which becomes intensely hot where the gas enters; not a trace of ozone passes out of the tube, and the gas measured in the aspirator is found to have undergone an increment of volume. The silver leaf and other substances employed in the following experiments were contained in small tubes of thin glass. The tube was kept during the experiment at the temperature indicated in column I. of the following Table: in which Table T is the "titre" of the gas; V is the volume of the gas before the experiment; V_1 is the volume of the gas after the experiment; $T+V$ is the sum of the "titre" of the gas and the volume of the gas before the experiment.

Temperature.	T.	V.	V_1.	T+V.
14°·7 C.	14·43	273·17	287·38	287·6
10° C.	9·33	273·22	282·45	282·55
——	9·1	272·97	282·05	282·07
——	8·98	272·23	280·39	281·21

It hence appears that the electrized gas when thus passed over metallic silver undergoes an expansion equal to the "titre" of the gas, precisely as though the gas were passed through a heated tube. The difference between the numbers in columns IV. and V. falls within the unavoidable errors of experiment, and is inappreciable, except perhaps in the last experiment. The quantity of oxygen retained by the silver must therefore in these experiments have been excessively minute. That this oxidation of the silver is nevertheless an integral part of the action, and although minute is still capable of estimation, appears from the following experiment, which was made with every precaution and with a special view of determining this point. The two experiments were made consecutively, without detaching from the apparatus the tube containing the silver.

T.	V.	V_1.	T+V.
9·68	270·27	278·61	279·95
9·68	269·67	277·77	279·35

Regarding these two observations as constituting a single experiment, the total volume measured in the aspirator after the experiment, namely the sum of the volumes in the two experiments headed V_1, is 556·38, whereas the sum of the volumes in the two experiments in the column headed T+V, column V., is 559·30; the difference between these volumes is 2·92 cub. centims., which, if the experiment be correctly conducted, represents the oxygen retained by the silver.

The tube containing the silver was now heated by means of a spirit-lamp, and the gas evolved measured in the aspirator; this gas amounted to 2·5 cub. centims., the difference between this number and the previous deficiency 2·92 cub. centims., that is 0·34 cub. centim., being the total amount of oxygen unaccounted for.

The oxide of silver here formed appears to be a peroxide of silver; for if a tube in which such an experiment has been made be washed out with a solution of iodide of potassium iodine is formed. That the minute quantity of the peroxide of silver thus formed is really an effective agent in determining the decomposition of the ozone, is rendered probable from the circumstance that the binoxide of manganese produces a precisely similar change (as to the decomposition of the ozone and the expansion of the gas) to that produced by silver, a small amount of oxygen being here also (if one experiment may be trusted) retained by the agent by which the decomposition of the ozone is effected, while the contact of the metals copper, gold, and aluminium produces no change whatever in the gas; these points are evident from the following experiments.

An experiment thus made with binoxide of manganese gave the following result:—

T.	V.	V_1.	T+V.
13·45	276·98	288·84	290·43

The difference between the numbers in the fourth and third columns, namely 1·59 cub. centim., represents the oxygen retained by the manganese.

The three following experiments were made in a precisely similar manner with the metals copper, gold, and aluminium, with the exception of a bulb containing iodide of potassium being placed immediately after the tube containing the metal; the "titre" of the gas after the experiment, T_1, as estimated in this bulb, is given in the last column.

	T.	V.	V_1.	T_1.
Copper	14·55	276·48	276·07	——
Gold	14·36	276·10	275·81	14·27
Aluminium...	14·17	275·52	274·61	14·20

It appears from these experiments that the "titre" of the electrized gas is precisely the same after the passage of the gas over these metals as before the experiments, and also that the volume of the gas is unaffected, the results being the same as though the gas had been passed through the solution of iodide of potassium alone.

When the electrized gas is passed through a solution of binoxide of sodium the ozone is destroyed, and a certain portion of the binoxide of sodium also is decomposed. This reaction is constantly referred to as an ascertained fact, but has never been really investigated. It was of great importance, in relation to the theory of this reaction, to ascertain by experiment the relation which exists between the two decompositions.

The points to be ascertained were:—the "titre" of the electrized gas, the oxygen lost by the binoxide of sodium, and the ratio of this oxygen to the "titre," also the expansion undergone by the electrized gas, the difference, that is, of the volumes of the gas after and before the experiment, and the ratio of this difference to the "titre" of the gas.

The oxygen lost by the binoxide of sodium was determined by titration of the solution of the binoxide of sodium before and after the experiment with a standard solution of permanganate of potash, according to the method described by me in a former paper*. From the difference between these two titrations the amount of oxygen lost by the binoxide of sodium may be calculated.

Since ozone is decomposed when brought in contact with a solution of caustic alkali, which substance is always present in the solution of binoxide of sodium, and, indeed, is a product of the decomposition of it by ozone, it was possible that errors in the exact estimation of the reaction might arise from this circumstance, as also from the spontaneous decomposition of the peroxide of sodium, which is especially rapid in a strongly alkaline solution. To guard against such errors, the binoxide of sodium in the first experiment was dissolved in water saturated with carbonic acid. Ozone, although

* Philosophical Transactions, 1862, vol. clii. p. 840.

destroyed by caustic soda, is totally unaffected even by a strong solution of carbonate of soda. This fact I have ascertained by experiment. In the last two experiments the volume of gas after the experiment was not measured.

In the next Table T is the "titre" of the gas.

V is the volume of the gas before the experiment.

V_1 is the volume after the experiment.

$V_1 - V$ is the increment in the volume of the gas.

$\frac{V_1 - V}{T}$ is the ratio of this increment to the "titre" of the gas.

P is the amount of oxygen lost by the binoxide of sodium, as estimated by titration calculated in cub. centims. at 0° C. and 760 millims.

P+T is the sum of the oxygen lost by the binoxide of sodium and the "titre" of the gas.

$\frac{P+T}{T}$ is the ratio of this sum to the "titre" of the gas.

T.	V.	V_1.	$V_1 - V$.	$\frac{V_1 - V}{T}$.	P.	P+T.	$\frac{P+T}{T}$.
3·92	269·84	277·4	7·56	1·93	4·19	8·11	2·06
7·42	273·81	288·62	14·81	1·99	8·70	16·12	2·17
3·23	——	——	——	——	3·26	6·49	2·00
3·34	——	——	——	——	3·61	6·95	2·08

It appears from these experiments that the ozone and the binoxide of sodium are decomposed in exactly equivalent proportions, and that in this decomposition equal volumes of oxygen are evolved from each of the two substances respectively, the reaction in this respect being similar to the decomposition of the peroxide of sodium by permanganic acid and ferrocyanide of potassium, and to the various deoxidations effected by the peroxide of hydrogen previously investigated by me, and discussed in a former communication to the Society*.

That this reaction has all the characters of a normal chemical decomposition occurring according to the law of definite and multiple proportions, is further proved by the following experiments, in which the binoxide of sodium was so dilute as to allow of the passage through it of a certain portion of the electrized gas with its properties unaltered. After the bulb containing the solution of binoxide of sodium a second bulb was placed, containing a solution of iodide of potassium; the difference between the original "titre" of the gas and the "titre" after the experiment of this solution is the "titre" of the ozone by which the decomposition of the binoxide of sodium is actually effected; and the ratio of the amount of oxygen, P, lost by the binoxide of sodium to this difference gives the proportion in which the oxygen is evolved from the two substances respectively.

T is the original "titre" of the gas.

T_1 the "titre" of the gas after its passage through the solution of binoxide of sodium.

* Philosophical Transactions, 1850, p. 759, and 1862, p. 840.

$T-T_1$ the "titre" of the gas destroyed by the binoxide of sodium.

P the amount of oxygen lost by the binoxide of sodium, ascertained by the titration with permanganate of potash in the way before mentioned.

$\frac{P}{T-T_1}$ the ratio of the volume of oxygen evolved from the binoxide of sodium to the volume of oxygen evolved from the electrized gas.

In these three experiments the solution of binoxide of sodium was saturated with carbonic acid.

T.	T_1.	$T-T_1$.	
7·98	3·96	4·02	0·98
2·41	0·08	2·33	1·11
1·27	0·05	1·22	1·04

There are doubtless numerous chemical substances which stand towards ozone in the same relation as iodide of potassium, and in which an oxidation may be effected by the electrized gas equal in amount to the "titre" of the gas without any alteration of its volume. Thus in two experiments in which the electrized gas was passed through a solution of the protonitrate of mercury, the two experiments being made consecutively and with the same solution, the following results were obtained:—

Volume of gas in the pipette.	Volume of gas in the aspirator.
268·14	267·21
267·95	268·05

the gas being deprived of its special oxidizing power, and the oxidation effected without alteration of its volume.

In the following experiments also, with protochloride of iron and protosulphate of iron, the oxidation effected is equal to the "titre" of the gas. In the case of protochloride of iron a measured quantity of the solution was "titred" before the experiment with permanganic acid, and the volume of oxygen required to effect its complete oxidation was determined. The solution through which the gas was passed was similarly "titred." From the difference between the "titre" of these solutions the oxidation effected by the electrized gas was estimated.

In the case of the protosulphate of iron, the ozone was not entirely destroyed by its passage through the solution, and a second bulb containing a solution of iodide of potassium was placed after the bulb containing the solution of protosulphate of iron; the difference of the original "titre" of the gas and the "titre" of the gas after its passage through the solution of protosulphate of iron gives the amount of oxidizing power lost by the electrized gas in its passage through that solution. The difference between the "titre" of the solution of the protosulphate of iron before and after the experiment gives the oxidation actually effected. The following is the result of one

experiment thus made with protochloride of iron, where T is the "titre" of the electrized gas, S the amount of oxygen corresponding to the actual oxidation effected, and $R=\frac{S}{T}$.

T.	S.	$R=\frac{S}{T}$.
3·197	3·218	1·00

In two experiments with protosulphate of iron, putting T as the original "titre" of the gas and T_1 as the "titre" of the gas after its passage through the solution of protosulphate, $T-T_1$ as the difference of the two "titres," S as the oxidation actually effected in the solution of protosulphate, and $R=\frac{S}{T-T_1}$, the following results were obtained:—

T.	T_1.	$T-T_1$.	S.	$R=\frac{S}{T-T_1}$.
1·124	0·080	1·044	1·003	0·97
1·122	0·134	0·988	1·042	1·05

From the discrepancy which existed between the oxidation of a solution of iodide of potassium, as indicated by the "titre," and the increment of weight of the same solution after the passage of the electrized gas, I was led to make the following experiment with a solution of protosulphate of iron, with the view of ascertaining whether or no a similar discrepancy would be found to exist in this case also. The experiment was arranged precisely as in the previous experiment referred to (p. 449).

A current of electrized gas was passed through a bulb containing a measured quantity of a nearly saturated solution of protosulphate of iron, which was weighed with the drying-tube attached before and after the experiment. The gain in weight was ·2125 grm. The oxidation effected, as estimated by titration with a standard solution of permanganate of potash before and after the experiment, corresponded to ·2184 gramme of oxygen. Now $\frac{\cdot 2184}{\cdot 2125}=\frac{100}{97\cdot 3}$, the oxidation indicated by the titration being rather less than that shown by the gain in weight of the solution, and the discrepancy being in the reverse direction to the discrepancy in the former case.

Hence it appears that the oxidation effected in these solutions exactly corresponds to and is equal to the "titre" of the electrized gas by which that oxidation is effected. The oxidation similarly effected in an acid solution of ferrocyanide of potassium and in a solution of arsenite of soda is of the same character; the experiments, however, which I now proceed to lay before the reader belong to a different order of phenomena.

SECTION III.

According to the statements of ANDREWS and TAIT, the action of ozone upon an acid solution of iodide of potassium is, as regards the amount of oxidation effected, identical with its action upon a neutral solution of iodide of potassium. "In some of the experiments the solution of iodide of potassium was slightly acidulated, in others it was neutral;" but "the results were the same whether the solution was taken in the neutral or in the acid state"*. The method is not mentioned by which a comparison was effected between these results; but the assertion is probably to be explained by the circumstance that these chemists experimented only with very dilute solutions of hydriodic acid, in which case the difference between the two oxidations, although by no means imperceptible, may not have been appreciated by their method of estimation. Out of many comparative experiments in no single case have I found the two oxidations to be identical. MEISSNER, on the other hand, who detected the essential difference in the case of the two oxidations, has fallen into an error of a different order, inferring the oxidation effected in the neutral iodide of potassium to be an altogether incorrect measure of the ozone contained in the electrized gas†. I shall hereafter recur to his experiments on this point.

The following experiments were among the first made by me as to the quantitative reactions of ozone, and were undertaken before the construction of the apparatus for exact measurement previously described, which accounts for some deficiencies in them.

The volume of gas before the experiment was measured in a gas-pipette, into which the gas was passed from a sulphuric-acid gas-holder substantially of the same construction as that previously described; the actual capacity of this pipette was 265·44 cub. centims., and the pipette contained a volume of gas which, at the temperature and pressure at which the experiments were made, was in round numbers equal to 250 cub. centims. at 0° C. and 760 millims. pressure. This volume does not in any way appear in the result of the experiment, and I shall speak of the volume of gas employed simply as a pipette of the electrized gas: this volume is assumed to be the same in consecutive experiments. which is not exactly true; for although the barometer may be considered constant for the short interval of the experiments, the temperature of the gas was subject to slight variation: this variation in extreme cases amounted to as much as 1° C. I have taken no cognizance of this point in the calculation of the experiments, as it could only affect the results to the extent of $\frac{1}{273}$ part, whence the error in the calculated result would appear only in the second decimal place, and be inappreciable.

The investigation of the action of ozone upon hydriodic acid is complicated by the analogous decomposition effected by the oxygen with which the ozone is invariably associated; in weak solutions of hydriodic acid this latter oxidation is extremely minute, but in strong solutions great errors would arise if it were not taken into account.

The oxidation effected by the passage of a pipette of oxygen through a solution of hydriodic acid of a known degree of concentration was determined by passing a pipette

* Philosophical Transactions, 1860, vol. cl. p. 121.

† MEISSNER, 'Neue Untersuchungen über den elektrisirten Sauerstoff,' 1869, p. 82.

of the gas through the solution of hydriodic acid contained in one of the small bulbs previously described, and estimating the oxidation effected with a standard solution of hyposulphite of soda in the usual manner. A strong solution of hydriodic acid invariably contains a certain amount of dissolved iodine; this amount was similarly estimated before the experiment in a quantity of the solution equal to that employed in it, and the number of cub. centims. of hyposulphite of soda employed in this titration was deducted from the number of cub. centims. of the same solution employed in the final titration. The difference represents the oxidation effected. The hydriodic acid was made of a definite strength by suspending in water a weighed quantity of iodine, and passing through the solution a current of sulphide of hydrogen, the acid being purified in the usual manner, a method sufficiently exact for the object in view.

The solution of hydriodic acid employed was measured, in all cases, in a small pipette of the same capacity, namely about 15 cub. centims. This quantity will be here termed a bulb of the solution.

The following experiments were made in the way described at a temperature of 18° C.

I. 16 cub. centims. of the solution contained about one gramme of iodine in the form of hydriodic acid; a bulb of this solution required for titration before the experiment 0·72 cub. centim. of the standard solution of hyposulphite. After the passage of the oxygen, the bulb of hydriodic acid required for titration 1 cub. centim. of the same standard solution, which gives 0·28 cub. centim. of hyposulphite as equivalent to the oxidation effected by the pipette of pure oxygen. One cub. centim. of the hyposulphite employed was equivalent to 0·0002814 gramme of oxygen. The oxygen therefore operative in the experiment for the decomposition of the hydriodic acid was certainly not more than ·000093 gramme. It was useless to attempt to follow the oxidation beyond this point.

II. 8 cub. centims. of the solution contained one gramme of iodine; the bulb of solution before the experiment required for titration 1·4 cub. centim. of hyposulphite and after the passage of the gas in two experiments 3·25 and 4 cub. centims. of the same. Taking the mean of these two experiments, 3·62 cub. centims., and deducting 1·4 cub. centim., we have 2·22 cub. centims. of the standard solution of hyposulphite of soda as the measure of the oxidation.

III. 4 cub. centims. of the solution contained one gramme of iodine in three experiments: the "titres" after the experiment were respectively 5, 7·5, and 6·75 cub. centims.; the "titre" before the experiment was 2·8 cub. centims., and the mean oxidation effected was equivalent to 3·61 cub. centims.

IV. 2 cub. centims. of the solution contained one grain of iodine; the "titre" after the experiment was in three determinations respectively 9·75, 9·75, and 10 cub. centims., and before the experiment 5·75, the oxidation effected being equivalent to 4·08 cub. centims.

V. In the case of a very strong solution of hydriodic acid, of which 1 cub. centim. contained one gramme of iodine, 22·75 cub. centims. of hyposulphite were required for

titration after the experiment and 14·2 before the experiment, the oxidation being equivalent to 8·5 cub. centims.

These numbers exhibit in experiments made under the same general conditions very appreciable differences, and in the case of very concentrated solutions of hydriodic acid, as in experiment V., undoubtedly become inaccurate from the oxidation of the hydriodic acid during the process of titration, and also to a certain extent from variations dependent on the rate of the passage of the gas through the solution, and the time for which the surface of the solution is consequently exposed to an atmosphere of oxygen. These differences, however, although undoubtedly a source of error, nevertheless are very small as compared with the total oxidation in the analogous experiments made with an electrized gas, and would hardly affect the result to more than one per cent., except in the extreme case given in experiment V.

The mean results of the preceding experiments are given in the two columns below. The numbers in column II. indicate the amount of oxidation effected by the passage of a pipette (that is about 250 cub. centims.) of pure oxygen at a temperature of 18° through a bulb, or (15 cub. centims.) of hydriodic acid, as estimated in cub. centims. of the standard solution of hyposulphite of soda. The degree of concentration of the hydriodic acid employed is indicated in column I., in which is given the number of cub. centims. of the solution containing one gramme of iodine. One cub. centim. of the hyposulphite employed was equivalent to 0·0002814 gramme of oxygen, whence the actual oxidation effected can be readily calculated. For the present object this is not necessary. The numbers marked † are interpolated from calculation, and are the mean of the two experiments between which they appear.

I.	II.
1 cub. centim.	——
2 "	4·08
†3 "	3·80
4 "	3·61
†6 "	3·00
8 "	2·22
†12 "	1·25
16 "	0·28

In determining the oxidation effected by the action of the electrized gas upon the solution of hydriodic acid, the total oxidation was estimated precisely as in the experiments just described; and a correction was made for the effect of the oxygen associated with the ozone by deducting from the number of cub. centims. of the standard solution of hyposulphite of soda which represented the total oxidation, the number of cub. centims. of the same hyposulphite of soda which represented the oxidation due to the passage of the pipette of oxygen through a solution of hydriodic acid of the strength employed in the experiment according to the preceding Table. This correction is made upon the hypothesis that the oxidation effected in the hydriodic acid is constituted of two distinct parts—namely, the oxidation effected by the ozone and the oxidation effected by the

oxygen with which it is associated, which are assumed to be separate and independent occurrences. The truth of this assumption, however probable it may appear, cannot be demonstrated by *à priori* reasoning; but if, proceeding upon this principle, it should be found that the ratio of the oxidation effected by the ozone to the "titre" of the gas under varying conditions has a constant value, there is every reason to believe the assumption to be substantially correct.

It is unnecessary to give the details of these experiments; but I will offer one or two examples to explain the mode of proceeding.

A pipette of electrized gas was passed through a neutral solution of iodide of potassium, which required for titration, after the passage of the gas, 12·5 cub. centims. of the standard solution of hyposulphite of soda.

A pipette of the same gas was passed through a bulb of hydriodic acid, 4 cub. centims. of which contained one gramme of iodine. The "titre" of the hydriodic acid, after the passage of the gas, was in two experiments respectively represented by 28·2 and 28·7 cub. centims. of the same hyposulphite of soda, deduction for the "titre" of the solution before the experiment having been made on the principles previously explained. Now 3·61 is the number given in the Table as that of the cub. centims. of the same hyposulphite of soda, which represents the oxidation due to the passage of a pipette of pure oxygen through a bulb of hydriodic acid of the degree of concentration employed in the experiment; subtracting this number from 28·2 and 28·7 respectively, we have 24·6 and 25·1 as the numbers representing the oxidation due to the action of the ozone; and putting R as the ratio of the oxidation of the hydriodic acid to the "titre" of the gas, we have, in the two experiments respectively, $R=\frac{24\cdot6}{12\cdot5}=1\cdot96$, and $R=\frac{25\cdot1}{12\cdot5}=2\cdot00$.

A similar experiment made with a solution of hydriodic acid, of which 2 cub. centims. contained one gramme, gave the following results:—

The "titre" of a pipette of the electrized gas with neutral iodide of potassium was represented by 19 cub. centims. of the standard solution of hyposulphite of soda.

The "titre" of a pipette of the same gas passed through the bulb of hydriodic acid was represented by 41·8 and 41·3 cub. centims. of the same hyposulphite; the correction for the influence of the associated oxygen is 4·1 cub. centims.; whence, subtracting this number from 41·8 and 41·3 respectively, we have 37·7 and 37·2 as the cub. centims. of the standard solution of hyposulphite representing the oxidation effected by the ozone in the several experiments, and we have for the values of R, $R=\frac{37\cdot2}{19}=1\cdot96$, and $R=\frac{35\cdot6}{19}=1\cdot87$.

The following experiment was made with a dilute solution of hydriodic acid, of which 16 cub. centims. contained one gramme of iodine, on which the action of pure oxygen would be almost imperceptible, the deduction according to the Table amounting to no more than 0·28 cub. centim.

The "titre" of a pipette of gas passed through neutral iodide of potassium was 12·5 cub. centims.; the "titre" of a pipette of the same gas passed through the solution of

hydriodic acid was 23·8 cub. centims.; deducting from this 0·3 cub. centim., we have 23·5 cub. centims. as representing the oxidation effected by the ozone, whence $R=\frac{23\cdot5}{12\cdot5}=1\cdot88$.

An experiment conducted in a perfectly similar manner, but with an exceedingly dilute solution of hydriodic acid, of which 256 cub. centims. contained one gramme of iodine, gave for the value of R, $R=\frac{14\cdot25}{12\cdot5}=1\cdot14$.

The following Table contains the record of a series of experiments made, precisely as were the experiments just described, with solutions of hydriodic acid, varying in their degree of concentration, which ranged from a solution containing one gramme of iodine in one cub. centim. to a solution containing one gramme of iodine in 256 cub. centims. For reasons which will presently appear, I have recorded in this Table all the experiments, without exception, which I have made upon this subject in the same way.

In column I. is given the degree of concentration of the hydriodic acid employed. In column II. is given the "titre" of a pipette of the gas with neutral iodide of potassium, T, as represented by the cub. centim. of hyposulphite of soda necessary for the titration. In column III. is given the "titre" of a pipette of the same gas with hydriodic acid, S, similarly represented. In column IV. is given the ratio of the oxidation effected in the hydriodic acid to the oxidation effected in neutral iodide of potassium, $R=\frac{S}{T}$.

I. Degree of concentration of the solution of hydriodic acid employed.	II. T.	III. S.	IV. $R=\frac{S}{T}$
1. 1 gramme of Iodine in 1 cub. centim.	19	36	1·89
2. " "	19	36	1·89
3. 1 gramme of Iodine in 2 cub. centims.	19	37·7	1·98
4. " "	19	37·2	1·96
5. " "	14·7	33·3	2·24
6. " "	14·7	32·3	2·20
7. " "	12·5	29·7	2·37
8. " "	12·5	29·7	2·37
9. 1 gramme of Iodine in 3 cub. centims.	23	42·2	1·83
10. " "	23	46·7	2·03
11. " "	23	48·7	2·11
12. " "	23	47·2	2·05
13. " "	15	27·6	1·84
14. " "	15	28·2	1·88
15. 1 gramme of Iodine in 4 cub. centims.	19	35·6	1·87
16. " "	15·5	33·3	2·15
17. " "	12·5	24·6	1·96
18. " "	12·5	25·1	2·00
19. " "	14·7	32·3	2·20
20. 1 gramme of Iodine in 6 cub. centims.	23	46·1	2·00
21. " "	23	44·1	1·91
22. " "	20	35·5	1·77
23. " "	18·7	40	2·13
24. " "	18·7	38·5	2·05
25. " "	15	27·2	1·81
26. " "	15	29·5	1·70

TABLE (continued).

I. [illegible]	II. T.	III. S.	IV. $R=\frac{S}{T}$.
27. 1 gramme of Iodine in 8 cub. centims............	15·5	31·4	2·02
28. " "	15·5	30·9	2·00
29. " "	12·5	25·4	2·03
30. 1 gramme of Iodine in 12 cub. centims.	23	42	1·82
31. " "	23	42·4	1·84
32. 1 gramme of Iodine in 16 cub. centims.	15	28·3	1·88
33. " "	15	28·5	1·88
34. 1 gramme of Iodine in 24 cub. centims.	23	37·7	1·64
35. " "	23	38·8	1·69
36. 1 gramme of Iodine in 48 cub. centims.	20	32·1	1·61
37. " "	20	31·3	1·57
38. 1 gramme of Iodine in 64 cub. centims.	12·5	18·9	1·51
39. 1 gramme of Iodine in 96 cub. centims.	20	28·1	1·40
40. " "	20	28·8	1·44
41. 1 gramme of Iodine in 128 cub. centims.........	12·5	17·2	1·40
42. 1 gramme of Iodine in 192 cub. centims.........	20	22·4	1·12
43. 1 gramme of Iodine in 256 cub. centims.........	12·5	14·2	1·14

It is evident on inspection of the Table that there is an appreciable diminution in the value of R in these experiments made with solutions of hydriodic acid containing less than one gramme of iodine in 16 cub. centims., and that in the last two experiments given, experiments 42 and 43, made with excessively dilute solutions, the oxidation in the solution of hydriodic acid closely approximates to the oxidation effected by the same gas in a solution of neutral iodide of potassium. This value, however, diminishes very gradually—the mean value of R in experiments 34 to 41 being 1·53, and the extreme values of R in experiments made the one with a solution of hydriodic acid containing 1 gramme of iodine in 24 cub. centims. and the other 1 gramme of iodine in 128 cub. centims. respectively being 1·66 and 1·40, the difference of which, 0·26, lies almost within the errors of experiment. In experiments 1 to 33 no regular variation is seen in the value of R, the mean value of this ratio for the first nineteen experiments given in the Table being 2·04, and the mean value of the same ratio for the following fourteen experiments being 1·92, the mean of the thirty-three experiments taken together being 1·99.

There are numerous causes of uncertainty in these experiments, several of which have already been pointed out; but it is impossible for us to apply any conjectural correction to the experiments, or to say how these causes have affected any particular experiment. With the view of determining the probable error of the result, I have applied to the system of experiments the method of least squares. Some of these experiments exhibit very considerable divergences from the mean result, but I have not ventured to reject any. A singular example of this divergence is exhibited in experiments 7 and 8, both

of which give 2·37 as the value of R. It might be thought at first sight that these experiments should be rejected, as affected by some special source of error; but, on the other hand, there is one value of R in the Table which exhibits a nearly equal divergence from the mean in the other direction, namely 1·7, experiment 26: also if we reject on these grounds the number 2·37, no adequate reason can be given for retaining such a number as 2·24; and I find, on turning to my note-book, that experiments 7, 17, 18, 8 were made successively on the same day, by the same method, under the same conditions, and by the same observer in the order of the preceding numbers, the value of R in the several experiments being (7) 2·37, (17) 1·96, (18) 2·00, (8) 2·37; and I cannot but attribute the divergence of these numbers from the mean to an accidental accumulation of errors in one direction.

In column I. of the following Table is given the value of R in each of the thirty-three experiments referred to; column II. contains the differences of these values from the mean value of R, and column III. the squares of the differences.

Experiments with Hydriodic Acid.

I. $R=\frac{S}{T}$.	II. Difference from the mean.	III. Squares of the differences.
1·89	−·1	·01
1·89	−·1	·01
1·98	−·01	·0001
1·96	−·03	·0009
2·24	+·25	·0625
2·20	+·21	·0441
2·37	+·38	·1444
2·37	+·38	·1444
1·83	−·16	·0256
2·03	+·04	·0016
2·11	+·12	·0144
2·05	+·06	·0036
1·84	−·15	·0225
1·88	−·11	·0121
1·87	−·12	·0144
2·15	+·16	·0256
1·96	−·03	·0009
2·00	+·01	·0001
2·20	+·21	·0441
2·00	+·01	·0001
1·91	−·08	·0064
1·77	−·22	·0484
2·13	+·14	·0256
2·05	+·06	·0036
1·81	−·18	·0324
1·70	−·29	·0841
2·02	+·03	·0009
2·00	+·01	·0001
2·03	+·04	·0016
1·82	−·17	·0289
1·84	−·15	·0225
1·88	−·11	·0121
1·88	−·11	·0121
Mean =1·99 cub. centim.		Sum=·8601

The number of these experiments is thirty-three.

Hence the probable error of the result $=0\cdot6745\sqrt{\frac{0\cdot8601}{33\times32}}$

$=0\cdot02$ cub. centim.;

and also

the probable error of a single experiment $=\sqrt{33}\times$ the probable error of the result

$=\sqrt{33}\times0\cdot02$

$=0\cdot11$ cub. centim.

It appears, therefore, from these experiments that it is an equal chance that the true value sought of the ratio R lies between the values 2·01 and 1·97. The value of this ratio indicated by chemical theory is 2; the preceding experiments, therefore, entirely agree with this theory. We may also infer, from the calculated value 0·11 of the error of a single experiment, that if we should proceed to make another experiment by the same method it is an equal chance that the value of R in that experiment will lie between the values 1·88 and 2·10; and half the values of R found by the preceding observations should lie between the same limits. As a matter of fact, out of these 33 experiments 17 experiments are within these limits, and 16 experiments are outside these limits. The experiments, therefore, are in perfect accordance with the calculated value of the probable error of a single result.

These experiments are fully confirmed by certain experiments of MEISSNER* previously referred to, which really throw great light upon the subject, although this chemist has the art of singularly misinterpreting his results. The object of the experiments was to effect a comparison between the weight of a volume of oxygen equal to the contraction of the electrized gas and the increment of weight of a solution of iodide of potassium, acidulated with sulphuric acid, when the same electrized gas was passed through the solution. The contraction was (as I understand the experiment) estimated by comparing the volume of the oxygen before and after its passage through the induction-tube, which was an induction-tube of the form devised by VON BABO; the weight corresponding to this contraction was then calculated, and the increment of weight of the acid solution of iodide of potassium was determined by weighing the apparatus in which it was contained before and after the experiment. I shall not pretend to criticise these experiments, the uncertainty of which is fully admitted by the author. Among other sources of error, however, the total increment of weight of the acid solution of iodide of potassium is comprised in the several experiments between a maximum of 0·016 gramme and a minimum of 0·005 gramme, quantities which it is evidently very difficult to estimate with precision in this way. I would rather direct the attention of the reader to the mean result of these twelve experiments, which gives 2·02 as the ratio of the increment of weight of the acid solution of iodide of potassium to the weight of a volume of oxygen equal to the contraction of the electrized gas. From these observations, taken in connexion with the Table of experiments before given, we may consider it as conclusively proved, not only that the oxidation

* Neue Untersuchungen über den elektrisirten Sauerstoff, 1869, p. 95, Tabelle F.

effected by the passage of an electrized gas through a solution of hydriodic acid amounts to twice the oxidation effected by the passage of the same gas through a solution of neutral iodide of potassium, but also that that oxidation is attended by an actual absorption of oxygen, the weight of which is equal to twice the weight of oxygen similarly absorbed by the neutral iodide.

The previous observations were made at the temperature of the laboratory, which was about 18° C. to 19° C. It was important to ascertain whether by varying the temperature the oxidation effected by the ozone could be carried beyond the limit thus reached. The following experiments were instituted with the view of determining this point; the gas was measured in a small pipette, the capacity of which was 94 cub. centims.

The influence of variation of temperature upon the oxidation of hydriodic acid effected by pure oxygen was first determined. In three concordant experiments made at the temperature of the laboratory, in which 92 cub. centims. of oxygen were passed through 15 cub. centims. of a concentrated solution of hydriodic acid, of which solution 2 cub. centims. contained 1 gramme of iodine, an oxidation was effected equivalent to 1·7 cub. centim. of the standard solution of hyposulphite. This oxidation is very nearly in the same proportion, in relation to the volume of oxygen passed through the solution, as that arrived at in the previous experiments, and would amount on 250 cub. centims. of oxygen to an oxidation represented by 4·6 cub. centims. of the hyposulphite, the number given in the Table for a solution of hydriodic acid of this strength being 4·1. The oxidation as similarly determined for the temperature of 53° C. to 55° C. (the mean being taken of four experiments) was equivalent to 4·6 cub. centims. of hyposulphite, and at 80° C., in two experiments, of which the results were nearly identical, to 6·35 cub. centims.

At a temperature, however, of 0° C., the bulb being immersed in water containing ice, the oxidation in four experiments was equivalent to 1·8, 1·9, 1·7, and 2·1 cub. centims. of hyposulphite, the mean of the four experiments being 1·9 cub. centim., a number slightly higher than that representing the oxidation at 18° C. to 19° C., namely 1·7 cub. centim. We may conclude, therefore, that the oxidation effected by the action of pure oxygen on a solution of hydriodic acid of the above strength is not materially affected by lowering the temperature from 18° C. to zero.

The two following experiments were made with a small pipette of the electrized gas at 55° C. In estimating the oxidation due to the influence of the ozone, a correction was made for the oxidation effected by the oxygen associated with it by deducting 4·6 from the number representing the total oxidation.

Experiments at 55° C.

I. Degree of concentration of the solution of hydriodic acid employed.	II. T.	III. S.	IV. $R=\frac{S}{T}$.
2 grammes of Iodine in 2 cub. centims.	31·4	59·8	1·90
" " "	31·4	60·4	1·92

The value of the ratio R is essentially the same as that previously arrived at. We may conclude, therefore, that while the oxidation effected by pure oxygen is raised from 1·7 at 18° C. to 4·6 at 55° C. (that is, nearly in the proportion of 1 to 3), the oxidation effected by the ozone is not appreciably altered by the same variation of conditions.

At the temperature of 0° C., however, exactly the reverse occurs; for while, as has been shown, the oxidation effected by pure oxygen at 0° does not sensibly differ from the similar oxidation at 18° C., the oxidation effected by the ozone is materially increased, as appears from the following experiments. The correction for the effect of the associated oxygen is here made by deducting 1·9 cub. centim. from the total oxidation.

Experiments with Hydriodic Acid at 0° C.

I. Degree of concentration of the solution of hydriodic acid employed.	II. T.	III. S.	IV. $R=\frac{S}{T}$.
2 grammes of Iodine in 2 cub. centims. ...	31·4	78·2	2·49
" " " ...	31·4	77·7	2·47
" " " ...	27·1	63·2	2·33
" " " ...	14·9	34·6	2·32
" " " ...	8·78	22·1	2·52
			Mean ... 2·43

When the electrized gas is passed through a solution of hyposulphite of soda, a certain oxidation of the hyposulphite is effected, and the gas undergoes a diminution in volume. These effects differ in neutral and alkaline solutions of the hyposulphite, and in the latter case vary with the amount of the alkali (carbonate of soda) contained in the solution. Of the action on neutral and slightly alkaline solutions I shall speak hereafter. The experiments of which the results are given in the following Table were made with a solution of hyposulphite of soda rendered strongly alkaline with carbonate of soda. The gas before the experiment was measured in the gas-pipette, and thence drawn through a bulb containing in most cases about 30 cub. centims. of the alkaline hyposulphite of soda into the aspirator, where the gas was again measured, the experiments being conducted precisely as described in Section II., p. 446.

In column I. of the following Table the relative strengths of the solutions of hyposulphite of soda are given in terms of the cub. centims. of oxygen at 0° C. and 760 millims., equivalent to the iodine employed for the titration of 1 cub. centim. of the solution, that is, in terms of the volume of oxygen required to effect the oxidation to tetrathionate of the amount of hyposulphite contained in 1 cub. centim. of the solution. In column II. is given the "titre" of the gas, T; in column III. the volume before the experiment, V; in column IV. the volume after the experiment, V_1; in column V. is given the contraction, $V-V_1$; in column VI. is given the ratio of the contraction to the "titre" of the gas, $\frac{V-V_1}{T}$. The temperature at which the experiment was made is also given.

Experiments with strongly alkaline Hyposulphite of Soda.

Temperature of experiment.	I. Strength of the solution.	II. T.	III. V.	IV. V_1.	V. $V-V_1$.	VI. $\frac{V-V_1}{T}$.
	grm.					
0° C.		3·47	87·16	83·85	3·31	0·95
0°	·89	10·98	273·00	264·84	8·16	0·74
0°	......	10·98	272·84	262·34	10·50	0·96
0°	......	10·98	272·09	262·89	9·20	0·84
0°	·94	12·95	273·73	262·39	11·34	0·87
0°	......	12·95	273·42	261·74	11·68	0·90
0°	2·45	7·53	273·76	264·69	9·07	1·20
15°	......	13·48	274·85	258·35	16·50	1·22
15°	......	13·48	274·57	257·95	16·62	1·23
15°	......	9·18	273·99	265·11	8·88	0·96
0°	......	7·53	270·94	262·43	8·51	1·13
0°	......	7·53	273·86	265·32	8·54	1·13
0°	......	9·79	275·71	266·12	9·59	0·98
0°	......	9·79	275·25	265·36	9·89	1·01
0°	......	9·79	274·94	265·60	9·34	0·95
0°	......	9·23	277·74	268·43	9·31	1·01
0°	......	9·23	277·25	265·22	12·03	1·33
14°	......	10·52	276·30	265·56	10·74	1·02
14°	......	8·37	270·48	261·17	9·31	1·11
16°	......	5·82	271·71	264·97	6·74	1·16
17°	......	9·44	275·93	264·97	10·96	1·16
18°	......	5·47	271·31	267·15	4·16	0·76
						Mean... 1·03

The conditions under which the experiments here given were made were greatly varied. They differ widely in the "titre" of the gas employed in the experiment, in the temperature at which the experiment was made, in the strength of the solution of hyposulphite through which the gas was passed, and in the amount of carbonate of soda present in that solution; but it is impossible to infer from these experiments that the ratio $\frac{V-V_1}{T}$ varies in any definite and regular manner with any one of these circumstances; and I have in this case also calculated, by the method of least squares, the probable error of the result.

In column I. of the following Table the values are given of the ratio $\frac{V-V_1}{T}$. In column II. the differences are given of the several values from the mean value of that ratio. In column III. the squares of these differences are given.

Experiments with strongly alkaline Hyposulphite of Soda.

I. $\frac{V-V_1}{T}$.	II. Differences from the mean.	III. Squares of the differences.
0·95	—·08	·0064
0·74	—·29	·0841
0·96	—·07	·0049
0·84	—·19	·0361
0·87	—·16	·0256
0·90	—·13	·0169
1·20	+·17	·0289
1·22	+·19	·0361
1·23	+·2	·04
0·96	—·07	·0049
1·13	+·1	·01
1·13	+·1	·01
0·98	—·05	·0025
1·01	—·02	·0004
0·95	—·08	·0064
1·01	—·02	·0004
1·33	+·3	·09
1·02	—·01	·0001
1·11	+·08	·0064
1·16	+·13	·0169
1·16	+·13	·0169
0·76	—·27	·0729
Mean= 1·03 cub. centim.		Sum=·5168

The number of these experiments is twenty-two.

$$\text{The probable error of the result} = 0{\cdot}6745\sqrt{\frac{0{\cdot}5168}{22\times 21}}$$
$$= 0{\cdot}022 \text{ cub. centim.};$$

and also

$$\text{the probable error of a single experiment} = \sqrt{22}\times\text{the probable error of the result}$$
$$= \sqrt{22}\times 0{\cdot}22$$
$$= 0{\cdot}1 \text{ cub. centim.}$$

We may conclude, therefore, from these experiments that it is an equal chance that the true value of the ratio $\frac{V-V_1}{T}$ lies between the value 1·01 and 1·05; also, if we should proceed to make another experiment by the same method, it is an equal chance that the value of the same ratio in that experiment would lie between the limits 1·13 and 0·93; and half the values of this ratio in the preceding twenty-two experiments should lie between the same limits. There actually are 11 values of $\frac{V-V_1}{T}$ in the preceding Table within these limits, and 11 of these values outside those limits. In this point, therefore, the experiments are in entire accordance with theory.

The theoretical value of the ratio $\frac{V-V_1}{T}$ lies just outside the limits of probable

error; but there is no doubt that the mean value of $\frac{V-V_1}{T}$ in these experiments is somewhat too high. I may especially notice two sources of error as constantly affecting these experiments in this direction for which I have not been able to apply a correction. When pure oxygen is passed through a solution of hyposulphite of soda, either alkaline or neutral, a minute but nevertheless real amount of oxidation occurs: this oxidation is far too minute to be estimated by measurement in the aspirator; but I endeavoured to gain some notion of its magnitude in the following way. A small pipette of oxygen, being 87 cub. centims. at 0° C. and 760 millims., was passed at a temperature of 14° C. in two experiments through an alkaline and a neutral solution of hyposulphite of soda respectively; the hyposulphite of soda was "titred" with a standard iodine solution before and after the experiment. In the case of the alkaline solution, the difference between the two titrations amounted to 0·7, and in the case of the neutral solution to 0·8 division of the burette; this would correspond in the previous experiments, in which about three times the amount of oxygen was passed through the solution, to an oxidation represented in the two experiments respectively by 2·1 and 2·4 divisions of the burette, representing an absorption of about 0·1 cub. centim. of oxygen by the alkaline solution of hyposulphite. The error from this source, although very small, affects every experiment in the same direction, and would appreciably affect the mean result—the value of the mean result, on the hypothesis that the contraction $V-V_1$ is in every case 0·1 cub. centim. in excess, being, as I have ascertained by calculation, 1·02. I have not, however, applied this correction, as there is no positive evidence that the oxygen, as thus calculated from the difference of the two titrations, represents the oxygen actually employed in the oxidation of the hyposulphite. The point also is immaterial. Another source of error is found in the gas simply dissolved by the solution of hyposulphite, which would not be estimated by this method of titration. Some idea of the magnitude of the error from this source may be derived from the experiments given in Section II. (page 446) with neutral iodide of potassium, where the volumes before and after the experiment (much the same quantity of gas being employed as in the present experiments), which theoretically should be identical, show a difference in their mean value of 0·2 cub. centim., for which difference we have an adequate cause in the absorption of 0·2 cub. centim. of oxygen by the neutral solution of iodide of potassium. Here, again, I have hesitated to apply a correction, which would be to a certain extent of an arbitrary character; but this is undoubtedly a real and constant cause of error operating in the same direction as the preceding; and if from these data we assume the contraction $V-V_1$ to be in all cases in excess by 0·3 cub. centim., the mean value of R would, after applying this correction, be as nearly as possible 1·00. The probable error of the result would not be appreciably affected.

In the experiments of which the result is given in the following Table the electrized gas was passed through a solution of polysulphide of barium, made by boiling a solution of the neutral sulphide with an excess of sulphur out of contact of air. The passage of

the gas is attended with a deposition of large quantities of sulphur. The experiment was conducted in all respects as the experiments with hyposulphite of soda last described, but the temperature was kept at 0° C. I have no record of the amount of polysulphide of barium contained in the solution; but the proportion of the polysulphide of barium in the several experiments was greatly varied, the relative amounts of the polysulphide contained in the bulb being, assuming the amount in experiment 1 as the unit of comparison, in experiments 2 and 3 twice that amount, in experiment 4 three times that amount, and in experiments 5 and 6 six times that amount.

Experiments with Polysulphide of Barium.

Experiment.	I. T.	II. V.	III. V_1.	IV. $V-V_1$.	V. $\frac{V-V_1}{T}$.
1.	12·60	267·97	254·73	13·24	1·05
2.	12·60	267·34	254·33	13·01	1·03
3.	11·94	268·68	255·79	12·89	1·08
4.	12·60	267·7	255·53	12·17	0·96
5.	12·60	268·15	254·33	13·82	1·09
6.	11·94	268·41	256·36	12·05	1·01
					Mean ... 1·04

The following experiments were conducted in a manner precisely similar to the preceding, but with a solution of polysulphide of sodium. The experiments were made at 0° C. In this case also the degree of concentration of the solution was very greatly varied, the amount of polysulphide of sodium employed being in experiment 11 six times that in experiments 2, 3, and 4, in experiments 8, 9, and 10 three times that in the same experiments, in experiments 5, 6, and 7 twice that in the same, and in experiment 1 two thirds that in the same. In experiment 1 a slight trace of ozone escaped the action of the polysulphide. With a solution half the strength of that in experiments 2, 3, 4 the ozone came distinctly through the solution when about half the gas had passed over.

Experiments with Polysulphide of Sodium.

Experiment.	I. T.	II. V.	III. V_1.	IV. $V-V_1$.	V. $\frac{V-V_1}{T}$.
1.	11·41	270·16	256·86	13·3	1·16
2.	15·15	272·84	257·04	15·80	1·04
3.	11·04	270·65	257·96	12·69	1·15
4.	13·24	272·37	257·15	15·22	1·15
5.	11·41	269·92	257·82	12·10	1·06
6.	10·2	271·04	258·4	12·64	1·24
7.	10·2	270·76	259·03	11·73	1·15
8.	13·24	273·57	258·74	14·83	1·12
9.	10·2	271·04	259·62	11·42	1·12
10.	11·04	270·65	258·68	11·97	1·08
11.	15·15	272·66	255·43	17·23	1·14
					Mean ... 1·13

The mean of these experiments is distinctly higher than the mean 1·04 of the previous experiments with polysulphide of barium; and while they point to the same general result, they also indicate the operation of a constant cause, causing a deviation in excess of the theoretical number 1.

The action of ozone upon the hydrosulphide of sodium (Na H S) appears to be of a different order. The following experiments were made with that substance at the temperature of the laboratory, which was about 20° C. The concentration of the solution in the five experiments severally commencing with experiment 1 was proportional to the numbers 1, 2, 4, 8, 16. The solution in experiment 5 was extremely concentrated.

Experiments with Hydrosulphide of Sodium.

Experiment.	I. T.	II. V.	III. V_1.	IV. $V-V_1$.	V. $\frac{V-V_1}{T}$.
1.	12·81	273·10	254·62	18·47	1·44
2.	12·81	273·37	253·19	20·18	1·57
3.	12·81	273·74	254·12	19·62	1·53
4.	12·81	274·29	252·71	21·58	1·68
5.	13·21	272·28	250·45	21·83	1·65
					Mean... 1·57

These experiments, made with solutions of such very different degrees of concentration, are nearly uniform in their result; at the same time they indicate a slight progression as the solution becomes more concentrated. An experiment made with a much weaker solution gave 1·21 for the value of $\frac{V-V_1}{T}$, while with a solution half the strength of this last the ozone came through. Considering these experiments in connexion with those made with hydriodic acid at the temperature of 0° C. (Section III. p. 459), I am inclined to believe that the ratio 1·5 indicates a definite pause in the oxidation. I have not pursued this part of the subject further; but I may mention that, in the case of two similar experiments made with the neutral sulphide of barium, 1·47 and 1·45 were obtained as the values of $\frac{V-V_1}{T}$; and in the case of one experiment with sulphide of potassium 1·62 was obtained for that value.

It would be very desirable to determine not only the contraction which the electrized gas undergoes in its passage through these various solutions, but also the oxidation actually effected in them. In the case of hyposulphite of soda I have made various attempts, and in different ways, to determine this point; but for some reason, which I do not quite understand, without satisfactory results, the different experiments not being so concordant as to be of much value: there can, however, be no reasonable doubt as to the amount of the oxidation effected—namely, that while the contraction is equal in amount to the "titre" of the gas, the oxidation is equal to twice that "titre;" for

the ozone after its passage through the solution of the alkaline hyposulphite is found to have lost its special oxidizing properties, and to have no effect whatever upon a solution of neutral iodide of potassium. Hence, to arrive at the amount of oxygen actually retained by the solution, we have to add the "titre" of the gas which is absorbed without change of volume to the contraction; moreover, in one case, namely that of hydriodic acid, this oxidation has been actually determined and found by experiment to be equal in amount to twice the "titre" of the gas with neutral iodide of potassium. In the case of the polysulphide of barium, again, the contraction is exactly equal in amount to the "titre" of the gas; and we may conclude from these experiments with certainty that, besides that class of oxidations of which examples were given in the last section, and which are attended with no change of volume in the gas, ozone is capable of acting upon various chemical substances in a totally different, but still perfectly definite way, and of effecting an oxidation equal to twice the amount effected in those cases where no change of volume occurs, and which oxidation is attended by a diminution in the volume of the gas equal to half the volume of the oxygen employed in effecting the oxidation.

Besides this there is in all probability another definite form of oxidation effected by ozone, which is represented by the oxidation of hydriodic acid at 0° C., and by the oxidation of hydrosulphide of sodium, and possibly also by the neutral sulphide of potassium and neutral sulphide of barium, in which the oxidation effected is equal to twice and a half the "titre" of the gas, and the contraction is equal to once and a half that "titre." In the next section I shall bring before the reader yet another definite class of reactions of ozone.

SECTION IV.

When the electrized gas is passed through a solution of neutral hyposulphite of soda, the gas undergoes a diminution of volume, as in the case of the alkaline hyposulphite, but different in amount. In the following Table I have collected the results of various experiments made by me at different times upon this subject. The experiments were conducted in the way previously described, and the conditions of the experiments were very greatly varied. The first four experiments in the Table were made without any special measuring-apparatus, the gas being simply collected in an ordinary graduated gas-jar and measured. In some cases the gas was passed very rapidly, and in others very slowly, through the solution; the strength of the solution of hyposulphite was also varied from an extreme degree of dilution, as in the first four experiments, to a degree of concentration of ten times that amount; the temperature also was varied from 0° C. in some experiments to 14° C. in others; but none of these variations produced any appreciable effect whatever upon the contraction of the gas.

The numbers in the second column represent the cubic centimetres of oxygen equivalent to the iodine required for titration of 1 cubic centimetre of the solution. About 30 cubic centimetres of the solution was the quantity usually employed.

Experiments with neutral Hyposulphite of Soda.

Temperature.	Strength of the solution.	T.	V.	V_1.	$V-V_1$.	$\frac{V-V_1}{T}$.
13°·5 C.	·36	3·95	87·84	79·66	8·18	2·07
13°·5	......	3·18	87·56	81·32	7·24	1·97
12°	......	3·50	87·47	80·45	7·02	2·00
14°	......	4·19	86·76	78·23	8·53	2·03
0°	·47	13·17	274·00	256·58	23·42	1·78
18°·6	·62	10·29	270·06	250·12	19·94	1·94
19°	......	10·29	269·69	249·38	20·31	1·97
0°	1·23	10·78	271·72	248·16	23·56	2·18
0°	1·75	12·06	273·18	248·53	24·65	2·04
0°	1·89	12·14	272·92	247·06	25·86	2·13
0°	......	12·14	272·70	246·34	26·36	2·17
0°	2·45	13·58	269·36	241·82	27·54	2·03
0°	......	13·58	268·78	240·45	28·33	2·08
0°	......	13·58	268·78	243·80	24·98	1·83
0°	......	12·61	268·15	240·74	27·41	2·17
0°	3·78	13·17	273·07	246·51	26·56	2·02
0°	......	12·14	273·82	249·17	24·65	2·03
						Mean ... 2·02

In the following Table the data are given for the calculation of the probable error in the result of these experiments.

Experiments with neutral Hyposulphite of Soda.

$\frac{V-V_1}{T}$.	Differences from the mean.	Squares of the differences.
2·07	+·05	·0025
1·97	—·05	·0025
2·00	—·02	·0004
2·03	+·01	·0001
1·78	—·24	·0576
1·94	—·08	·0064
1·97	—·05	·0025
2·18	+·16	·0256
2·04	+·02	·0004
2·13	+·11	·0121
2·17	+·15	·0225
2·03	+·01	·0001
2·08	+·06	·0036
1·83	—·19	·0361
2·17	+·15	·0225
2·02	·00	·0000
2·03	+·01	·0001
Mean = 2·02 cub. centims.		Sum = ·1950

The number of these experiments is seventeen.

The probable error of the result $=0·6745\sqrt{\frac{0·195}{17\times 16}}$

$=0·017$ cub. centim.;

the probable error of a single experiment $=\sqrt{17}\times$ the probable error of the result

$$=\sqrt{17}\times 0{\cdot}017$$

$$=0{\cdot}07 \text{ cub. centim.}$$

It appears, therefore, from these experiments that it is an equal chance that the true value of the ratio $\frac{V-V_1}{T}$ lies between the limits 2·00 and 2·04. The theoretical value of this ratio, 2, is within these limits, and the experiments are in accordance with theory. At the same time it cannot be doubted that here also, from the causes previously indicated in the case of the similar experiments made with alkaline hyposulphite (Section III.), the mean experimental value of this ratio, 2·02, is somewhat too high; also, from the calculated value of the probable error of a single experiment, 0·07, half the values of $\frac{V-V_1}{T}$ given in the preceding Table might theoretically be expected to be found within the limits 2·09 and 1·95. Of the seventeen experiments, nine are within these limits, and eight outside them. The experiments, therefore, in this point also agree with theory.

The solution of hyposulphite of soda, originally neutral, is found, after the passage of the ozone, to have become strongly acid. Considering that the acid thus formed might exercise some important influence upon the reaction, I experimented with solutions of hyposulphite of soda rendered slightly alkaline with carbonate of soda. The influence of a great excess of carbonate of soda is, as has been shown, to reduce the oxidation, so that the contraction in the case of the strongly alkaline solution is only half the contraction in the case of the neutral solution. I therefore (with the view of adding only a slight excess of alkali) estimated by titration the amount of carbonate of soda required to render the solution neutral after the passage of the gas, and added to the solution employed in the experiment two or three times that amount. This amount of carbonate of soda was sufficient to keep the solution alkaline during the experiment, without, as will be seen, sensibly reducing the oxidation effected by the electrized gas. When about this quantity of carbonate is added the solution is spoken of as slightly alkaline. The following ten experiments were thus conducted. The Table below is of the same nature as the preceding.

Experiments with slightly alkaline Hyposulphite of Soda.

Temperature.	Strength of the solution.	T.	V.	V_1.	$V-V_1$.	$\frac{V-V_1}{T}$.
0° C.	·05	1·60	87·34	83·96	3·38	2·09
16°	·50	13·41	272·31	243·93	28·38	2·10
0°	·94	12·95	274·11	250·49	23·62	1·82
0°	......	12·95	273·89	249·31	24·58	1·90
16°	·85	13·81	272·50	243·69	28·81	2·13
0°	1·75	9·79	274·75	254·44	20·31	2·07
0°	......	9·79	274·66	254·12	20·54	2·10
14°·5	......	10·52	274·92	255·89	20·03	1·90
15°	......	13·81	273·63	245·18	28·45	2·06
15°	......	13·81	272·88	244·95	27·93	2·02
						Mean 2·02

The following Table contains the differences of the value of $\frac{V-V_1}{T}$ in the case of the several experiments from the mean value of that ratio and the squares of the differences.

$\frac{V-V_1}{T}$.	Differences from the mean.	Squares of the differences.
2·09	+·07	·0049
2·10	+·08	·0064
1·82	−·2	·04
1·90	−·12	·0144
2·13	+·11	·0121
2·07	+·05	·0025
2·10	+·08	·0064
1·90	−·12	·0144
2·06	+·04	·0016
2·02	·0	·0
Mean =2·02		Sum =·1027

The number of these experiments is ten.

$$\text{The probable error of the result} = 0{\cdot}6745\sqrt{\frac{0{\cdot}1027}{10\times 9}}$$
$$= 0{\cdot}023 \text{ cub. centim.};$$

and also

$$\text{the probable error of a single experiment} = \sqrt{10}\times\text{the probable error of the result}$$
$$=\sqrt{10}\times 0{\cdot}023$$
$$= 0{\cdot}07 \text{ cub. centim.}$$

We may, therefore, from these experiments regard it as an equal chance that the true value of the ratio $\frac{V-V_1}{T}$ is included between the limits 2·00 and 2·04.

From the value of the probable error of a single experiment, 0·07, half the above observations would theoretically be included within the limits 1·95 and 2·09; four of the ten observations are actually within these limits, and six external to them.

In none of the previous experiments have I rejected any experiment as untrustworthy; but in the case of these experiments, made with the slightly alkaline solution of hyposulphite of soda, I have rejected seven experiments which were made successively at the same period, and which from some cause, of which I am not aware, but possibly some slight derangement of the measuring-apparatus, gave a mean result considerably above the average of the preceding experiments. I do not believe that these seven experiments are to be relied on; but as it is an important question whether any definite contraction greater than that found in the preceding experiments can actually occur, and as the discrepancy between these seven experiments and the preceding may possibly be otherwise accounted for, it appears to be desirable to notice the circumstance, and I have given in the following Table the record of the observations.

Temperature.	Strength of the solution.	T.	V.	V_1.	$V-V_1$.	$\frac{V-V_1}{T}$.
16° C.	1·75	8·37	270·29	250·99	19·30	2·30
16°	......	5·82	272·18	259·66	12·52	2·15
16°	......	5·82	271·89	259·03	12·86	2·21
17°	......	13·44	274·01	245·89	28·12	2·09
17°	......	9·44	275·84	253·23	22·61	2·39
18°	......	5·42	271·04	259·00	12·04	2·20
17°	......	4·92	273·13	262·17	10·96	2·22
						Mean ... 2·22

It is to be observed, that not only is the mean value in these experiments, 2·22, considerably greater than the mean value in the preceding experiments, 2·02, but that every one of these experiments gives a result greater than that mean value. As no intentional difference was made in the mode of conducting the two sets of experiments, and as the previous set are in entire accordance with the experiments made with neutral hyposulphite of soda, the obvious conclusion is that the discrepancy in the latter set arises from the operation of some constant and accidental cause of error peculiar to those experiments.

I now repeated the experiment of SORET*, and passed the electrized gas through a bulb of oil of turpentine, measuring the volume before and after the experiment in the usual manner; the tension of the vapour of oil of turpentine was taken into account in the calculation of the volume of the gas in the aspirator after the experiment, care being taken to saturate the gas with it. Although I speak of this experiment as a repetition of the experiment of SORET, it really differs from that experiment, not only in the method employed for measuring the gas, but also in the gas operated on, the gas used by SORET being the ozone procured by electrolysis, and his experiments, moreover, being always made with a moist gas.

It was desirable to ascertain whether any change in volume was caused in pure oxygen by passing a pipette of that gas through a bulb of oil of turpentine. The results of three experiments made with this view were as follows: the several pipettes of oxygen were passed successively through the same oil of turpentine at a temperature of 9° C.

* Annales de Chimie, 4e série, vol. vii. p. 113.

V.	V_1.	$V-V_1$.
282·33	282·09	+0·24
282·00	282·14	−0·14
282·13	282·12	+0·01

The differences in the last column are hardly appreciable by the method employed, and we may conclude that any error in the following experiments arising from the oxidation of oil of turpentine by oxygen in its ordinary condition must be very small.

In the first two experiments given in the following Table the gas was rendered moist before its passage through the oil of turpentine; in the other experiments the gas was, as usual, dry.

Experiments with Oil of Turpentine.

Temperature.	T.	V.	V_1.	$V-V_1$.	$\frac{V-V_1}{T}$.
11° C.	14·29	281·27	251·24	30·03	2·09
11°	14·29	281·16	254·16	27·00	1·88
0°	13·93	280·85	250·60	30·25	2·17
0°	13·93	280·55	252·57	27·98	2·01
10°	14·22	280·14	251·04	29·10	2·04
10°	14·22	279·74	253·39	26·35	1·85
0°	9·16	282·45	263·52	18·93	2·06
0°	9·16	282·35	262·95	19·40	2·11
					Mean 2·02

In the following Table the differences from the mean and the squares of the differences are calculated.

$\frac{V-V_1}{T}$.	Differences from the mean.	Squares of the differences.
2·09	+0·07	·0049
1·88	−0·14	·0196
2·17	+0·15	·0225
2·01	−0·01	·0001
2·04	+0·02	·0004
1·85	−0·17	·0289
2·06	+0·04	·0016
2·11	+0·09	·0081
Mean =2·02 cub. centims.		Sum =·0861

The number of these experiments is eight.

The probable error of the result $=0{\cdot}6745\sqrt{\frac{{\cdot}0861}{8\times 7}}$

$$=0{\cdot}03 \text{ cub. centim.};$$

and also

the probable error of a single experiment $=\sqrt{8}\times$ the probable error of the result

$$=\sqrt{8}\times 0{\cdot}03$$

$$=0{\cdot}08 \text{ cub. centim.}$$

These experiments are also in accordance with theory; for it appears from them that it is an equal chance that the true value of the ratio $\frac{V-V_1}{T}$ is included within the limits 1·99 and 2·05.

Also, *from the probable error of a single experiment, half the preceding* observations would theoretically be included within the limits 1·94 and 2·10; four out of the eight experiments are within these limits, and four external to them.

Sufficient evidence is afforded of the value of the oxidation which occurs in the case of the contractions considered in Section III. (where the contraction is equal to the "titre" of the gas) by the experimental determination of the oxidation effected in the case of hydriodic acid; which oxidation is exactly represented by an amount of oxygen equal to that which disappears in the contraction in the case of the strongly alkaline hyposulphite of soda, together with the titre of the gas. With the view of determining this point in the class of contractions considered in the present Section, I have made various experiments with protochloride of tin, in the case of which substance the oxidation effected, as well as the change in the volume of the gas, may be determined with considerable accuracy. These experiments, however, are attended with peculiar difficulties, not only from the facility with which the protochloride of tin is oxidized and the influence which very slight variations of circumstances (such as the strength of the tin solution and the rate of the passage of the gas) have upon the oxidation, affecting the result in various ways, but also from the circumstance that the oxidation effected by the action of the ozone and that effected by the oxygen associated with it are in all probability not independent of one another—owing to the occurrence of that remarkable induced oxidation which has been noticed and made the subject of investigation, in the case of the oxidation of the protochloride of tin by chromic and permanganic acids, by F. KESSLER*, and also by LENSSEN and LÖWENTHAL†, so that we cannot apply a correction for the oxidation effected by the associated oxygen on the simple principle employed in the case of hydriodic acid. However, by operating with very dilute solutions the influence of these sources of error may be, if not entirely destroyed, at any rate very greatly reduced; and the following experiments afford conclusive evidence as to the actual oxidation effected in those cases also where the contraction is equal in amount to twice the "titre" of the gas.

It appears from the three following experiments, that when an electrized gas is passed through an acid solution of protochloride of tin, the total oxidation which takes place is equal in amount to that due to the "titre" of the gas, together with the oxidation due to a volume of oxygen equal to the contraction which occurs in the experiment.

The oxidation of the protochloride of tin was determined by running an amount of the tin solution equal to that employed in the experiment into a measured quantity of a standard iodine solution greater in amount than that required to effect the oxidation of the tin. The excess of iodine was estimated with a standard solution of hypo-

* POGG. Ann. xcvi. 332, and cxix. 218. † J. Pr. Chem. lxxxvi. 193; Jahresbericht, 1862, p. 38.

sulphite of soda; a similar estimation was made with the solution after the experiment. From the difference between the amounts of hyposulphite respectively employed in the two cases, the oxidation effected in the tin solution was calculated in cub. centims. of oxygen.

The volume of the gas before the experiment was measured in a small gas-pipette; the gas after the experiment was collected and measured in an ordinary graduated jar.

In the following Table S is the oxidation effected in the protochloride of tin as experimentally determined, T, V, V_1 have their previous signification.

T.	V.	V_1.	$V-V_1$.	S.	$\frac{V-V_1}{T}$.	$\frac{S}{T}$.
3·86	90·40	80·02	10·38	15·31	2·69	3·93
3·24	89·24	81·30	7·94	11·75	2·45	3·63
2·92	88·37	80·25	8·12	11·09	2·78	3·78

If the e[illegible] coincided with the view above given, we shou[illegible]ve $\frac{S}{T}=1+\frac{V-V_1}{T}$.

Also, if we deduct the "titre" of the gas from the total oxidation, the difference gives the oxidation due to the gas which disappears in the contraction, and the ratio of this difference to the contraction gives the density of this gas as compared with the density of oxygen. Calling this density Δ, we have in the three experiments successively:

$$(1)\quad \Delta=\frac{11·45}{10·38}=1·10.$$

$$(2)\quad \Delta=\frac{8·51}{7·94}=1·07.$$

$$(3)\quad \Delta=\frac{8·17}{8·12}=1·00.$$

We may conclude from these experiments that, by the oxidation of the solution of protochloride of tin, nothing whatever is removed from the electrized gas, except the quantity of oxygen estimated in the "titre" of the gas, together with a certain volume of gas of the density and properties of oxygen.

In the two following experiments I attempted to discriminate between the oxidation effected by the ozone and the oxidation due to the oxygen associated with it; this was done by causing the gas, after being deprived of ozone by its passage through the bulb of protochloride of tin, to pass through a second bulb of the same solution, in which also the oxidation was afterwards estimated. The oxidation in the second bulb was taken as the measure of the oxidation due to the oxygen associated with the ozone, and the difference between the oxidation effected in the two bulbs respectively was assumed to be the true oxidation effected by the ozone. In this mode of operating the two oxidations were effected under precisely similar circumstances as regards the temperature and rate of passage of the gas, and are strictly comparable.

Before the experiment the oxygen required to effect the complete oxidation of the

bulb of protochloride of tin was estimated by running a bulb of the solution into a measured quantity of hypochlorite of soda, of which the oxidizing value had been previously determined by effecting its decomposition by means of an acid solution of iodide of potassium, and estimating the iodine formed with a standard solution of hyposulphite of soda. A solution of iodide of potassium was added to the solution of hypochlorite of soda before the addition of the protochloride of tin. The bulb of protochloride of tin was then run into the solution, which was immediately acidified with hydrochloric acid, and the iodine estimated as before. A similar experiment was made after the completion of the experiment with each of the two bulbs of protochloride of tin employed in it; the oxidation effected was calculated, as in the former method, from the difference between the two titrations. This method gives good and accurate results; the contraction was not estimated.

The experiments were made at 0° C. The strength of the protochloride of tin is given in the first column: Q is the oxidation in the second bulb, S−Q is the oxidation estimated as due to the ozone, and the ratio $\frac{S-Q}{T}$ given in the last column is the ratio of this oxidation to the "titre" of the gas.

Strength of the solution.	T.	S.	Q.	S−Q.	$\frac{S-Q}{T}$.
3·78	8·98	30·95	1·28	29·67	3·3
7·07	8·98	37·36	7·06	30·3	3·37

It will be observed that in the second of the two experiments the strength of the tin solution employed was nearly double the strength of the solution employed in the former of the two experiments; and the oxidation effected by the passage of the associated oxygen was so greatly increased that the oxidation in the second bulb, in the latter experiment, amounted to nearly as much as six times the oxidation effected in the same bulb in the former experiment: nevertheless, when the correction has been applied for this oxidation, the number representing the oxidation due to the ozone is almost the same as in the former experiment; and this oxidation, thus calculated, closely approximates to three times the "titre" of the gas. The coincidence of this result in the two experiments affords a guarantee of the accuracy of the principles on which the process depends.

The two following experiments were made with an extremely dilute solution of protochloride of tin, on which, under the circumstances of the experiment, pure oxygen has but very little action. In the second of the two experiments the solution was so dilute that no inconsiderable portion of the ozone passed unaltered through the solution. To estimate the amount of ozone actually effective for the oxidation of the tin, the gas after its passage through the bulb of protochloride of tin was passed through a second bulb of neutral iodide of potassium, in which the ozone which escaped from the deoxidizing influence of the tin salt was arrested and estimated.

In these experiments the contraction as well as the oxidation was estimated with the following results:—

Strength of the solution.	T.	V.	S.	T_1.	V_1.	$T-T_1$.	$V-V_1$.	$\frac{V-V_1}{T-T_1}$.	$\frac{S}{T-T_1}$.
·96	8·15	269·55	25·41	0	251·69	8·15	17·86	2·19	3·12
·7	8·15	268·92	19·83	1·68	253·85	6·47	15·07	2·33	3·07

We thus, through two perfectly independent methods of experiment, arrive at the same conclusion—namely, that when a current of electrized oxygen is passed through a solution of protochloride of tin, the amount of oxidation effected in that solution by the ozone present in the gas is equal to three times that effected by the "titre" of that gas, and also that the gas undergoes a diminution in volume equal to the space occupied under normal conditions by a quantity of oxygen equal to twice that "titre."

If the experimental results were perfectly concordant with theory, we should have

$$\frac{S}{T-T_1}=1+\frac{V-V_1}{T-T_1}.$$

We have also for the value of Δ, the density of the gas absorbed, as compared with the density of oxygen, after subtraction of the "titre" in these two experiments, as estimated from the equation

$$\Delta=\frac{S-(T-T_1)}{V-V_1}:$$

$$(1)\quad \Delta=\frac{17\cdot26}{17\cdot86}=0\cdot97,$$

$$(2)\quad \Delta=\frac{13\cdot37}{15\cdot07}=0\cdot88,$$

against the theoretical value $\Delta=1$.

These results depend in each case upon the successful performance of at least five independent experiments, each of which again depends upon various other observations. The successive performance of these numerous experiments without any considerable error or mistake is truly difficult, and we need not be surprised if a certain divergence appears between the actual and the theoretical result.

The various experiments recorded in the three preceding sections constitute a body of exact information as to the chemical properties of ozone, through which it may be hoped that this important question will be finally removed from the domain of arbitrary speculation and brought within the precincts of science. It only remains to consider the bearing which these facts have upon the theory of the subject.

We may first remark that in the total system of experiments no evidence whatever is afforded of the existence in the electrized gas of any other "simple weight" than the "simple weight"* ξ, and the hypothesis of ANDREWS and TAIT as to the decomposition of oxygen by the electric discharge has no support in facts. I shall therefore assume the unit of ozone to be constituted of some number of these "simple weights;" and as a

* Philosophical Transactions, 1866, pp. 792, 805, 810; J. Chem. Soc. 1868, vol. vi. p. 367.

diminution of volume occurs when the oxygen is submitted to the action of electricity, I shall further assume that (the unit of oxygen being symbolized as ξ^2) ozone is some denser form of oxygen, to which the symbol ξ^{2+n} (where n is a positive integer) is to be assigned. Writing also $[\xi]$ as the symbol of that "simple weight" ξ which is transferred to the oxidized substance in the various oxidations effected by ozone, the result of the total system of experiments, of which an account has here been given, may be expressed, so far as regards the distribution of the matter of the unit of ozone in those reactions, by the general equation

$$(p+q)\xi^{2+n}=q\xi^2+(p(2+n)+qn)[\xi],$$

where p, q, n are positive integers, $p+q$ the number of units of ozone which are effective in the reaction, q the number of units of oxygen formed, and $p(2+n)+qn$ the number of the "simple weights" $[\xi]$ transferred.

We have, then, putting T as the "titre" of the gas, $V-V_1$ as the contraction, S as the oxidation, and $R=\frac{V-V_1}{T}$ and $r=\frac{S}{T}$, since $T=\frac{(p+q)n}{2}$,

$$R=\frac{2p}{(p+q)n}, \quad r=\frac{p(2+n)+qn}{(p+q)n}=R+1.$$

Considering the preceding experiments we have four cases brought before us.

$$\text{Case I.} \quad R=0,\ r=1,$$
$$p=0\ ;\ \text{the equation becomes}$$
$$\xi^{2+n}=\xi^2+n[\xi].$$

In this case no diminution occurs in the volume of the gas. Examples of this case are afforded in the various experiments given in Section II.,—namely, the oxidation of neutral iodide of potassium, the oxidation of the protochloride and protosulphate of iron, and other similar phenomena. These experiments throw no light whatever on the value of n, and any assumption as to this value based upon them is purely speculative and conjectural.

$$\text{Case II.} \quad R=1,\ r=2,$$
$$p(2-n)=qn.$$

Examples of this class are supplied in Section III.; such are the oxidation of hydriodic acid, the oxidation of the strongly alkaline solution of hyposulphite of soda and of the pentasulphide of barium.

We may here make two hypotheses as to the value of n:

$$\text{Hypothesis (1)} \quad n=1,\ p=q,\ \text{whence}$$
$$2\xi^3=\xi^2+4[\xi]\ ;$$
$$\text{Hypothesis (2)} \quad n=2,\ q=0,\ \text{whence}$$
$$\xi^4=4[\xi].$$

According to hypothesis (1) the density of ozone is once and a half that of oxygen;

according to hypothesis (2) the density of ozone is twice that of oxygen. The experiments are perfectly consistent with either of these two assumptions, and both hypotheses are equally tenable.

$$\text{Case III.}\quad R=\tfrac{3}{2},\ r=\tfrac{5}{2},$$
$$p(4-3n)=3qn.$$

The experiments with hydriodic acid at zero, and also the experiments with hydrosulphide of sodium, given in Section III., are to be referred to this case; only one hypothesis is possible:

$$\text{Hypothesis, } n=1,\quad p=3q;\ \text{whence}$$
$$4\xi^3=\xi^2+10[\xi].$$

$$\text{Case IV.}\quad R=2,\ r=3,$$
$$p(1-n)=qn.$$

The experiments comprised in Section IV. (namely, the oxidation of neutral and slightly alkaline solutions of hyposulphite of soda, the oxidation of oil of turpentine and of protochloride of tin) are examples of this class.

But one hypothesis is possible:

$$\text{Hypothesis, } n=1,\ q=0;\ \text{whence}$$
$$\xi^3=3[\xi].$$

The hypothesis, therefore, that the unit of ozone is constituted of three "simple weights" ξ is both necessary and sufficient for the explanation of the total system of phenomena, and no other hypothesis of this order is tenable.

XVIII. *Experiments on the Directive Power of large Steel Magnets, of Bars of magnetized Soft Iron, and of Galvanic Coils, in their Action on external small Magnets.* *By* George Biddell Airy, *Astronomer Royal, C.B., P.R.S.—With Appendix, containing an Investigation of the Attraction of a Galvanic Coil on a small Magnetic Mass. By* James Stuart, *Esq., M.A., Fellow of Trinity College, Cambridge.*

Received January 6,—Read February 8, 1872.

The only experiments with which I am acquainted tending to throw light upon the distribution of magnetic power in the different parts of a steel magnet are some very imperfect ones by Coulomb in the French Memoirs for 1789 and other years. It appeared to me that it might be desirable to make experiments of a rather more extensive character, and to add some measures of the magnetic effect of galvanic currents, both directly by their immediate action, and indirectly by the amount of magnetic power which they produce inductively in soft iron.

For the measure of permanent magnetism I selected a bar magnet 14 inches long, 1·4 inch broad, 0·35 inch thick; it has not been touched by a magnet for several years, and is likely to be in a state of very permanent magnetism. For the galvanic currents a cylindrical coil was used 13·4 inches long, 1·4 inch in external diameter, and about 0·9 inch in internal diameter; it has, I believe, four layers of wire, each layer having 160 revolutions of the wire. The battery used with it consisted of three cells, with sulphuric acid diluted in the proportion of 1 to 6; the plates were of zinc and graphite, each exposing on each side about 8 square inches; the circuit was always completed about half an hour before the experiments were begun, and a delicate galvanometer was placed in circuit by which the steadiness of the current was established. A core of iron 0·8 inch in diameter and of the same length as the coil, removable at pleasure, fits well in the inside of the coil; the iron is quite soft, and can with ease be entirely freed from any subpermanent magnetism.

The first step in the experiment was to neutralize terrestrial magnetism within the area of magnetic experiment. For this purpose two powerful 2-feet magnets were placed below the table on which the experiments were made, with their red or north-seeking ends directed to the magnetic north, at a distance (determined by trial) such that the experimental compass was sensibly uninfluenced by terrestrial magnetism. It is possible that some small residual magnetism was perceptible in the comparison with the feeble galvanic action, but none could be certainly discovered in the other experiments.

The compass used for register of the magnetic action is a small and very lively pocket-compass, with needle 1·0 inch long, not loaded with a card. The box of this compass

is circular, and when positions had been selected for the centre of the compass (as will be mentioned), a circle somewhat larger than the compass-box was described in pencil with each of those positions for centre; and the compass could then be planted with its centre very accurately placed above the intended point.

The compass-positions were thus prepared:—Upon a sheet of strong paper the plan of the magnet, 14 inches by 1·4 inch, was laid down. On each side were drawn two parallel lines of the same length as the magnet, at distances respectively 1·5 inch and 3·0 inches from the near edge of the magnet; these lines were divided each into ten equal parts, and thus in each line eleven points were obtained at intervals of 1·4 inch. From each of the four angles of the magnet as centre, two quadrants were swept—one with radius at 1·5 inch, at whose extremity and bisection points were taken for the compass-centre; and one with radius 3·0 inches, which was twice bisected, and of which the extreme point and the three bisection-points were taken for the compass-centre. These points were used for the magnet both with its edge and with its flat side towards the compass. A similar process was adopted in using the galvanic coil, with this difference only, that the longitudinal separation of the points taken for compass-centre was only 1·34 inch.

A solid piece of wood was provided, in which was cut a concave channel, less than half a cylinder, such that when the galvanic coil, or the large magnet with its flat side towards the compass, was laid in the channel, its axis was sensibly at the same height as the needle of the small compass. With the magnet's edge towards the compass, that condition was sufficiently secured by merely laying its flat side upon the board. The paper with station-points, being laid in proper position upon the board and secured by nails, was cut along the middle of the channel and crosswise at its ends, so that it could be bent down into the channel to permit the magnet or coil to take its proper position; when observations were finished, the paper was detached from the board, and the edges which had been cut were re-united by cementing a piece of paper behind.

The observation (as will be seen) consisted, in every case, of observation of the direction taken by the small needle. And this observation was made solely by the eye. The observer, looking endways of the small needle, made two pencil dots upon the paper, corresponding to the line of the needle-axis produced as it appeared to his eye. If, from erroneous position of the eye, a parallactic error is produced in the position of the two pencil dots, this error is detected as soon as the compass has been removed and an attempt has been made to draw a line of direction through the station-point of the compass; and, to correct it, all that is required is, to draw through the station-point a line parallel to the line joining the two dots. The whole of this operation is extremely accurate.

For measuring the intensity of the magnetic force exerted on the compass-needle, I determined, after consideration, to adopt the statical method; that is, to place a constant magnet in a definite position above the compass-needle, with its magnetic axis transversal to the direction which the compass-needle had taken before the constant magnet was

introduced, and to observe the deflection produced. The measure of the force of the large magnet was then the cotangent of the angle of deviation. The observation of the deflected needle by dots &c. was the same as before; but the angle of deviation was never measured by degrees. Instead of that measure, a circle upon semitransparent paper was graduated by cotangents, and thus the measure of the force of the large magnet was read off at once.

The arrangements in this state were confided to Mr. CARPENTER, Assistant of the Royal Observatory, by whom all the subsequent arrangements were planned and all the observations were made. I need not say that they were made with the utmost skill and delicacy.

A small frame was constructed, carrying a floor at a definite position about 1·8 inch above the compass-needle. As it was my object to make the observations at small distances from the great magnet, where its power is great, it was necessary to use a large power in the deflecting magnet. Mr. CARPENTER selected a horse-shoe magnet about 4 inches long, consisting of sixteen plates, each 0·06 inch thick; these were retouched a few days before they were used. From the consistency of the results obtained at the beginning and end of each circuit of the great magnet, I am entitled to conclude that no sensible change took place in the magnetism of the horse-shoe magnet. The magnet was placed in a vertical position, its two poles resting on the raised floor above mentioned. In all cases the deflecting magnet was used in the two positions to produce deflection right and deflection left.

These arrangements sufficed for observation of the powers of the great magnet in both positions, and also for observation of the galvanic coil carrying the soft iron core, the intensity of the battery having been in some measure adjusted to make the power of the coil with core not very different from that of the magnet. But when the coil was used without core, the force was so enormously reduced that the arrangement which applied well in the other cases failed totally in this. A small magnet was then used, 1·25 inch long, not very strongly magnetized; its deflecting power was compared with that of the horse-shoe magnet in the following way:—The small compass being under the influence of the earth's magnetism, the horse-shoe magnet and the small magnet were successively placed on the raised floor above mentioned, then 0·5 inch higher, then 1·0 inch higher, and the cotangents of deflection were compared. Thus the following proportions were obtained:—

Magnets upon the raised floor . . . . . $\frac{\text{power of small magnet}}{\text{power of horse-shoe magnet}}=\frac{1}{107}$.

Magnets 0·5 inch above the raised floor . $\frac{\text{power of small magnet}}{\text{power of horse-shoe magnet}}=\frac{1}{136}$.

Magnets 1·0 inch above the raised floor . $\frac{\text{power of small magnet}}{\text{power of horse-shoe magnet}}=\frac{1}{125}$.

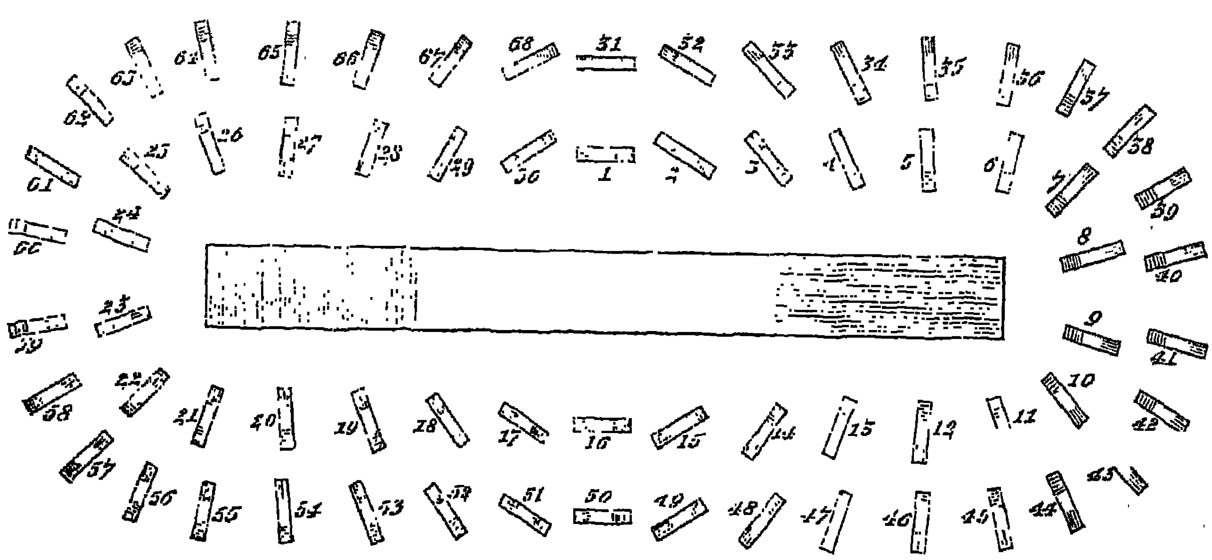
With so great inequality the results are necessarily irregular. I use $\frac{1}{120}$ as the pro-

portion for comparison, without asserting that it is accurate. All results obtained for the coil without core ought therefore to be divided by 120, to make them comparable with the other results.

The results obtained for the direction of magnetical force now consisted of lines drawn upon paper. Upon examining these, some very small irregularities were found—generally of systematic character, partly arising from minute failure in the neutralization of terrestrial magnetism, partly from a difference in the intensity of the poles of the great magnet; these were eliminated by the following graphical process:—The paper was bent upon its longitudinal axis, and exposed to a strong light passing through the two folds of paper; the lines drawn upon both sides of the magnet or coil were visible, and a mean line bisecting the small angle between each pair was easily drawn. Then the paper was unfolded and was bent upon its transversal axis, and a similar operation was performed upon the mean lines mentioned above. Thus for one fourth part of the circumference of the magnet a series of lines was obtained representing the mean of the four parts; these mean lines, repeated for the four divisions of the magnet's or coil's circumference, are alone used in further graphical deductions and in the subjoined figure.

The results, however, for magnitude of force were obtained in numbers. The means of these were taken in an analogous order—first taking the sums of those on opposite sides of the magnet or coil, then taking the sums of the last-found sums for opposite ends. The division by 4 was omitted; and thus the numbers in the Table below give the value of 400 × cotangent of deviation. At two stations the proximity of the coil-terminals made it difficult to obtain actual observations; but there was no difficulty in supplying them conjecturally, with great confidence in their accuracy.

The diagram below was drawn carefully to represent the positions taken by the small magnet when the edge of the large magnet is presented to the small magnet. The same diagram will serve, almost without perceptible error, for the case when the flat side of the large magnet is presented to the small magnet, or for the case of a galvanic coil



inclosing an iron core; but it will not apply to the case of a galvanic coil without an iron core: for that case the axis of the small magnet in the positions numbered 35, 5,

12, 46, and all to the right of it must be directed almost exactly to the centre of the right-hand end of the magnet, and a similar direction must be made at 65, 27, 20, 54 in respect of the left end, with corresponding changes for intermediate stations.

The angles of position were never measured, but they are fully taken into account in the subsequent resolution of forces into longitudinal and transversal components.

The following Table exhibits the total force at each station, as ascertained by the operations described above. It will be remembered that the numbers for the "Galvanic coil with iron core" are not necessarily on the same scale as those for the "Large magnet," and that the numbers for the "Galvanic coil without core" must be divided by 120 to make them comparable with those for the "Galvanic coil with iron core."

Total force acting on the small magnet at each station.

No. of Station.				Large magnet presenting its edge.	Large magnet presenting its flat side.	Galvanic coil with iron core.	Galvanic coil without core.
1	16			274	250	310	216
2	15	17	30	326	293	330	240
3	14	18	29	408	363	413	333
4	13	19	28	566	480	515	550
5	12	20	27	678	542	634	1000
6	11	21	26	622	480	585	1470
7	10	22	25	513	454	565	1925
8	9	23	24	600	584	840	2700
31	50			160	160	164	184
32	49	51	68	163	165	180	192
33	48	52	67	191	183	195	225
34	47	53	66	224	200	221	305
35	46	54	65	235	217	227	400
36	45	55	64	211	197	215	427
37	44	56	63	193	180	200	444
38	43	57	62	175	173	195	485
39	42	58	61	181	177	208	583
40	41	59	60	201	193	227	690

Perhaps the following points are worthy of present notice:—

1. Remarking that, in the experiment in which the edge of the large magnet is presented to the small magnet, the distance of the small magnet is in each circuit the same at every station, it will be seen that the greatest directive force is not longitudinal at the end of the magnet, but transversal, at about $\frac{1}{10}$ part (or probably less) of the length from the end of the magnet. There is, however, a diminution and then an increase in proceeding from either of these positions to the other, and the directive force opposite the middle of the magnet's length is less than either of them; so that, in making the entire circuit of the magnet, there are six maxima and six minima.

2. When the flat side is presented to the small magnets, the same statement holds for the outer circuit, but not for the inner circuit.

3. With increase of distance, the diminution of force is much more rapid at the end than at the side of the large magnet.

4. The law of effect of a soft iron bar surrounded by a galvanic coil differs, but not greatly, from that of the large magnet presenting its edge. It would seem not improbable that this may depend partly on the effect of the coil which incloses the iron bar; and, if so, the law for a soft iron bar approaches still more to that of a magnet.

5. The exhibition of the effect of the magnetic coil alone is worthy of careful examination. The first thing which will strike the eye is the astounding increase of power produced by the insertion of the soft-iron core. At the sides of the magnet, where the measures of force for the coil alone are 1·5 and 1·8, those for the coil with core inclosed are 164·0 and 310·0; at the ends, where the coil alone gives 5·75 and 22·5, the coil with core included gives 227·0 and 840·0.

6. The law of magnitude of forces for the coil alone differs greatly from that of a steel magnet. In the inner circuit the proportion of the force at the end to force at the middle of length is, for the steel magnet $\frac{600}{274}$, for the coil $\frac{2700}{216}$; in the outer circuit they are $\frac{201}{160}$ and $\frac{690}{184}$.

7. Still more remarkable is the difference in the law of direction of the forces near the ends. Using the term "pole" to denote that point near the extremity to which the directions of forces rudely converge, the pole of the steel magnet is within the magnet, and distant from the end by about $\frac{1}{12}$ of the magnet's length: but the pole of the galvanic coil is absolutely at its end; indeed some of the experimental directions of force fall a little beyond the end.

It is evident, from the remarks of Nos. 6 and 7, that a magnet cannot in any wise be represented as a system of revolving galvanic currents, with an equal number of circuits at every part of its length.

With the view of presenting the results in the form which may probably be found most advantageous for comparison with the conclusions from any future theory, I have resolved the forces into rectangular directions, parallel and transversal to the axis of each magnet, by the following graphical process. Upon each mean line of direction of force (ascertained as is described above) I have laid down the mean measure of the force (as found above), and upon this measure as hypotenuse I have constructed a right-angled triangle, the lengths of whose sides give the two forces. From the nature of the preceding operations, it is only necessary to form these numbers for one quadrant of each magnet. The results are given in the following Tables. The centre of the large magnet or coil is in every case the origin of coordinates of the external magnetic point on which the action of the large magnet &c. is estimated—the axis of the longitudinal ordinate being the axis of the magnet, and the axis of the transversal ordinate being normal to it. The powers are estimated as those of the red end of the large magnet operating on a small external mass of red magnetism. It will be remembered that, for the galvanic coil without core, all the numbers must be divided by 120.

Large Bar Magnet.

For attracted point.		Edge towards small magnets.		Flat side towards small magnets.	
Longitudinal ordinate.	Transversal ordinate.	Longitudinal force.	Transversal force.	Longitudinal force.	Transversal force.
0·0	2·2	−274	0	−250	0
1·4	2·2	−283	+161	−260	+137
2·8	2·2	−262	+315	−236	+276
4·2	2·2	−198	+530	−182	+444
5·6	2·2	− 56	+678	− 36	+540
7·0	2·2	+216	+585	+158	+451
8·08	1·76	+367	+360	+325	+315
8·5	0·7	+580	+166	+552	+184
0·0	3·7	−160	0	−160	0
1·4	3·7	−147	+ 73	−149	+ 72
2·8	3·7	−127	+142	−123	+136
4·2	3·7	− 88	+205	− 79	+185
5·6	3·7	− 19	+235	− 12	+217
7·0	3·7	+ 49	+205	+ 51	+190
8·13	3·5	+ 95	+167	+ 92	+154
9·12	2·8	+129	+122	+124	+118
9·79	1·84	+159	+ 88	+157	+ 82
10·0	0·7	+199	+ 42	+190	+ 40

Galvanic Coil.

For attracted point.		Coil with iron core.		Coil without core.	
Longitudinal ordinate.	Transversal ordinate.	Longitudinal force.	Transversal force.	Longitudinal force.	Transversal force.
0·0	2·26	−310	0	− 216	0
1·34	2·26	−286	+169	− 240	+ 38
2·68	2·26	−252	+327	− 315	+ 120
4·02	2·26	−193	+477	− 450	+ 325
5·36	2·26	− 42	+632	− 550	+ 848
6·7	2·26	+162	+562	− 80	+1480
7·78	1·70	+380	+420	+1010	+1630
8·2	0·74	+790	+296	+2480	+1170
0·0	3·73	−164	0	− 134	0
1·34	3·73	−162	+ 82	− 189	+ 41
2·68	3·73	−124	+149	− 200	+ 104
4·02	3·73	− 88	+201	− 217	+ 212
5·36	3·73	− 19	+226	− 123	+ 383
6·7	3·73	+ 39	+214	− 57	+ 424
7·83	3·44	+ 94	+176	+ 100	+ 436
8·82	2·8	+134	+149	+ 264	+ 410
9·49	1·82	+186	+ 99	+ 475	+ 338
9·7	0·73	+223	+ 44	+ 668	+ 186

It does not appear possible to infer from these numbers, by any direct analytical process, the law of distribution of magnetism in the bar. It must be done, I believe, synthetically, by assuming a law, and computing the forces which would result from that law, and then comparing these computed forces with the forces actually observed. The only law which I have tried is the supposition that the intensity of magnetism is

proportional to the distance from the centre of the magnet, which includes also the laws that there is a gradual increase of red magnetism from one end and a gradual increase of blue magnetism from the other end. Putting l for the half-length of the magnet, a and b for the longitudinal and transversal ordinates of the attracted point, x for the longitudinal ordinate (measured from the centre) of any attracting point, and supposing the magnet to be a line, it is easily seen that the quantities to be integrated are:—

$$\text{Longitudinal } \frac{-x(x-a)}{\{(x-a)^2+b^2\}^{\frac{3}{2}}}, \quad \text{Transversal } \frac{-bx}{\{(x-a)^2+b^2\}^{\frac{3}{2}}};$$

and the results of integration are:—

$$\text{Longitudinal force } = \frac{l}{\{(l+a)^2+b^2\}^{\frac{1}{2}}} + \frac{}{\{(l-a)^2+b^2\}^{\frac{1}{2}}}.$$

$+\text{hyp. log}\,\{\overline{(l+a)^2+b^2}|^{\frac{1}{2}}-l-a\}-\text{hyp. log}$ [illegible].

$$\text{Transversal force } = \frac{-al-a^2-b^2}{b\{(l+a)^2+b^2\}^{\frac{1}{2}}} + \frac{-al+a^2+b^2}{b\{(l-a)^2+b^2\}^{\frac{1}{2}}}.$$

I have computed these numbers for each of the eighteen stations. For comparison with observation, I have taken the experiments with the flat side towards the small magnets, which represents most nearly the case of a linear large magnet; and, for facility of comparison, I have multiplied the experimental numbers by 6. The following is the comparison:—

Experimental.		Theoretical.	
Longitudinal.	Transversal.	Longitudinal.	Transversal.
−1500	0	−1849	0
−1560	+ 822	−1750	−1089
−1416	+1656	−1441	−2112
−1092	+2664	− 827	−2928
− 216	+3240	+ 155	−3180
+ 948	+2706	+1126	−2283
+1950	+1890	+1589	−1389
+3312	+1104	+2395	− 622
− 960	0	−1029	0
− 894	+ 432	− 971	+ 517
− 738	+ 816	− 776	+ 960
− 474	+1110	− 428	+1267
− 72	+1302	− 2	+1319
+ 306	+1140	+ 335	+1066
+ 552	+ 924	+ 409	+ 801
+ 720	+ 708	+ 668	+ 633
+ 942	+ 492	+ 805	+ 380
+1140	+ 240	+ 984	+ 251

The agreement is not satisfactory; but I am unable to suggest the nature of the change that ought to be made in the assumed law.

I shall add only one remark, of a somewhat practical character. In a paper published originally by Dr. LAMONT in POGGENDORFF'S 'Annalen,' vol. cxiii. p. 239 &c., and of which

a translation, by W. T. LYNN, Esq., of the Royal Observatory, is printed in the Philosophical Magazine, 1861, November, Dr. LAMONT inferred the proportion of the effects of different steel magnets from the proportion of the effects of different soft iron bars under the influence of induction. The remark No. 4 (above) goes far, I think, to justify this assumption.

APPENDIX.

Remarking the singularity of the experimental result as to the apparent localization of the attractive pole of a galvanic coil at the very extremity of the coil, I commenced an investigation of the theoretical attraction of a coil, on the laws of galvanic attraction usually received. On my mentioning the subject to my friend JAMES STUART, Esq., Fellow of Trinity College, Cambridge, he kindly undertook, at my request, to prepare a complete theoretical investigation. I am happy in being permitted by Mr. STUART to place before the Royal Society his mathematical discussion of the attraction of the coil, which I am confident will be found to be very complete and of great elegance. I append to it a comparison of the numerical results of the theory with the numerical results of experiment; and the agreement will be found to be so great as to justify entire confidence in the assumed law of galvanic action and the mathematical treatment of it, and a high estimate of the accuracy of the experimental observations.

Investigation of the Attraction of a Galvanic Coil on a small Magnetic Mass.

By JAMES STUART, *M.A., Fellow of Trinity College, Cambridge.*

Received July 26,—Read December 5, 1872*.

From investigations given by AMPÈRE, we can deduce an expression for the potential U at an external point Q of a closed circular galvanic current carried by a wire of indefinitely small section. Let a be the radius of the circle, let the distance of Q from C, the centre of the circle, be r, and let the line C Q make an angle θ with the normal to the plane of the circle: then it can be shown that when r is less than a,

$$U=2\pi k\left\{-1+\frac{r}{a}P_1-\frac{1}{2}\frac{r^3}{a^3}P_3+\frac{1.3}{2.4}\cdot\frac{r^5}{a^5}\cdot P_5-\ldots\right\};$$

and when r is greater than a,

$$U=2\pi k\left\{-\frac{1}{2}\frac{a^2}{r^2}P_1+\frac{1.3}{2.4}\cdot\frac{a^4}{r^4}P_3-\frac{1.3.5}{2.4.6}\cdot\frac{a^6}{r^6}P_5+\ldots\right\},$$

* Abbreviated from the Appendix originally presented and read with the paper.

where k depends only on the intensity of the current, and where P_1, P_3, P_5 are defined by the equation

$$\frac{1}{\sqrt{1-2x\cos\theta+x^2}}=1+P_1x+P_2x^2+P_3x^3+\ldots.$$

If, therefore, X represents the resolved part, perpendicular to the plane of the circle and towards it, of the force exerted by the current on a unit of magnetism placed at Q, and if Y represent the resolved part of that force parallel to the plane of the circle and directed from its centre outwards, then

$$X=\frac{dU}{r\,.\,d\theta}\sin\theta-\frac{dU}{dr}\cos\theta,$$

$$Y=\frac{dU}{r\,.\,d\theta}\cos\theta+\frac{dU}{dr}\sin\theta.$$

To calculate these quantities, we know that

$$P_1=\cos\theta,$$
$$P_2=\tfrac{5}{2}(\cos^3\theta-\tfrac{3}{5}\cos\theta),$$
$$P_3=\tfrac{63}{8}(\cos^5\theta-\tfrac{10}{9}\cos^3\theta+\tfrac{15}{63}\cos\theta).$$

We shall only consider the case of those points for which r is greater than a. Substituting these values in the expression which in such instances holds for U, we have

$$U=2\pi k\left\{-\tfrac{1}{2}\,.\,\frac{a^2}{r^2}\cos\theta+\tfrac{15}{16}\,.\,\frac{a^4}{r^4}(\cos^3\theta-\tfrac{3}{5}\cos\theta)\right.$$
$$-\tfrac{315}{128}\,.\,\frac{a^6}{r^6}(\cos^5\theta-\tfrac{10}{9}\cos^3\theta+\tfrac{15}{63}\cos\theta)$$
$$\left.+\ldots\right\}.$$

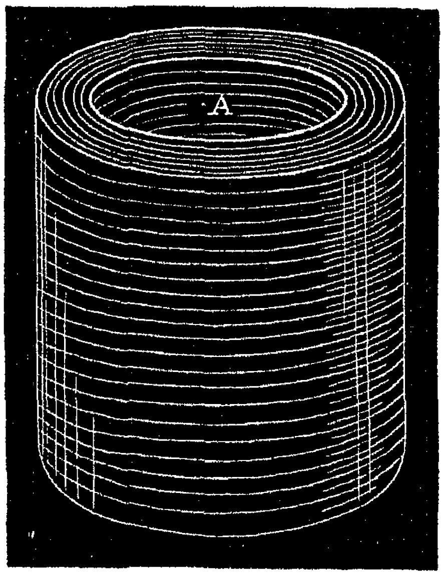
From which, after some reduction, we obtain

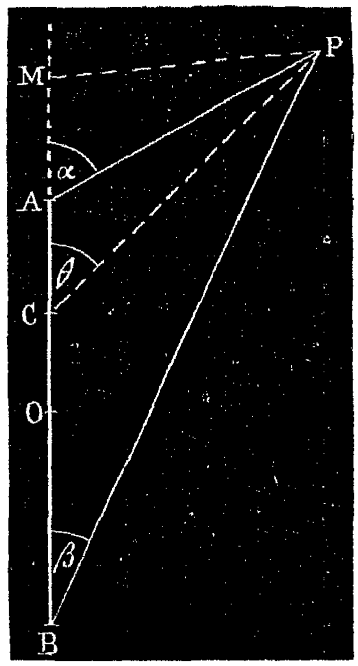
$$\frac{X}{2\pi k}=-\tfrac{1}{2}(-1+3\cos^2\theta)\frac{a^2}{r^3}+\tfrac{1}{16}\,.\,(9-90\cos^2\theta+105\cos^4\theta)\frac{a^4}{r^5}$$
$$-\tfrac{1}{128}(-75+1575\cos^2\theta-4725\cos^4\theta+3465\cos^6\theta)\frac{a^6}{r^7}$$
$$+\ldots\ldots, \qquad (1)$$

$$\frac{Y}{2\pi k}=\sin\theta\,.\left\{+\tfrac{3}{2}\cos\theta\,.\,\frac{a^2}{r^3}-\tfrac{1}{16}(-27\cos\theta+105\cos^3\theta)\frac{a^4}{r^5}\right.$$
$$+\tfrac{1}{128}(525\cos\theta-3150\cos^3\theta+3465\cos^5\theta)\frac{a^6}{r^7}$$
$$\left.-\ldots\ldots\right\}. \qquad (2)$$

Each of these expressions consists of a series of terms in ascending powers of $\frac{a}{r}$, which will be converging.

We shall now seek to find X and Y for a galvanic current traversing a wire coiled into the form of a hollow cylinder, of which the internal radius is b, the external radius $b+c$, and the length is $2f$. We shall suppose the individual turns of the wire to lie so close as that each may be regarded as an exact circle.





Let A B be the axis of the coil, so that A and B are the centres of its two faces; then $AB=2f$. Let O be the middle point of A B. Let P be the attracted point, P M its perpendicular distance p from A B. Let $PAM=\alpha$, $PBM=\beta$.

Let C be the centre of any turn of the wire regarded as a circle of radius a, $CP=r$, $PCM=\theta$, $OC=x$; then it is readily seen that for the whole cylindrical bobbin the forces X, Y are given by

$$\frac{X}{\mu}=\int_{-f}^{+f}\int_{b}^{b+c}L\,dx\,da,$$

$$\frac{Y}{\mu}=\int_{-f}^{+f}\int_{b}^{b+c}M\,dx\,da,$$

where L and M stand for the expressions on the right-hand side of (1) and (2) respectively, and where μ depends on the strength of the current.

To perform the integrations for the length of the bobbin in these expressions, we have the formulæ

$$p=r\,.\sin\theta,$$

$$\delta x\,.\sin\theta=-r\,.\,\delta\theta;$$

$$\therefore\ \delta x=\frac{-p\delta\theta}{\sin^2\theta},$$

and

$$r=\frac{p}{\sin\theta}.$$

Making these substitutions for δx and r, the integrals with respect to x become integrals with respect to θ, which can be easily evaluated by a continued application of the method of integration by parts, the limits being from $\theta=\alpha$ to $\theta=\beta$. If we then integrate the

result thus obtained with respect to a, from the limit b to the limit $b+c$, we finally obtain

$$\frac{\mathrm{X}}{\mu}\ \overline{b+c}^3-b^3\,\{-(\cos\beta-\cos\alpha)+(\cos^3\beta-\cos^3\alpha)\}$$

$$+\frac{\overline{b+c}^5-b^5}{80p^4}\{-\quad 9(\cos\beta-\cos\alpha)+33(\cos^3\beta-\cos^3\alpha)$$
$$-\quad 39(\cos^5\beta-\cos^5\alpha)+15(\cos^7\beta-\cos^7\alpha)\}$$

$$\overline{b+c}^7-b^7\{-\quad 75(\cos\beta-\cos\alpha)+\ 575(\cos^3\beta-\cos^3\alpha)$$
$$-1590(\cos^5\beta-\cos^5\alpha)+2070(\cos^7\beta-\cos^7\alpha)$$
$$-1295(\cos^9\beta-\cos^9\alpha)+\ 315(\cos^{11}\beta-\cos^{11}\alpha)\}$$
$$+\dots$$

$$\frac{\mathrm{Y}}{\mu}=\frac{\overline{b+c}^3-b^3}{6p^2}\{+(\sin^3\beta-\sin^3\alpha)\}$$

$$+\frac{\overline{b+c}^5-b^5}{80p^4}\{-\ 12(\sin^5\beta-\sin^5\alpha)+15(\sin^7\beta-\sin^7\alpha)\}$$

$$+\frac{\overline{b+c}^7-b^7}{896p^6}\{+120(\sin^7\beta-\sin^7\alpha)-420(\sin^9\beta-\sin^9\alpha)+315\,(\sin^{11}\beta-\sin^{11}\alpha)\}$$
$$+\dots\dots$$

These expressions for X and Y will be converging for all points situated at a greater distance than $b+c$ from any point of the axis AB, inasmuch as they are composed by adding together corresponding terms of series which are then all convergent. Among other points, these expressions hold for such as are situated on the axis external to the bobbin, and not nearer A or B than by the distance $(b+c)$. For such points, however, the expressions become illusory, assuming the form $\frac{0}{0}$; they may, however, be evaluated by the methods for the evaluation of vanishing fractions. Y is clearly zero. X may be more readily obtained directly from the expression for U; from that expression we find that for a single circular current the attraction on such points is

$$\mathrm{X}=2\pi k\left\{+\frac{a^2}{r^3}-\frac{3}{2}\frac{a^4}{r^5}+\frac{15}{8}\frac{a^6}{r^7}-\dots\right.$$

Hence, in the case of a bobbin, if x be the distance of the attracted point from O, the middle point of the axis of the bobbin, we have

$$\frac{\mathrm{X}}{\mu}=\int_{x+f}^{x-f}\int_b^{b+c}dr\,da\left(+\frac{a^2}{r^3}-\frac{3}{2}\frac{a^4}{r^5}+\frac{15}{8}\frac{a^6}{r^7}-\dots\right)$$
$$=-\frac{\overline{b+c}^3-b^3}{6(x^2-f^2)^2}(\overline{x+f}^2-\overline{x-f}^2)$$
$$+3\frac{\overline{b+c}^5-b^5}{40(x^2-f^2)^4}(\overline{x-f}^4-\overline{x-f}^4)$$
$$-5\frac{\overline{b+c}^7-b^7}{112(x^2-f^2)^6}(\overline{x+f}^6-\overline{x-f}^6)$$
$$+\dots\dots,$$

which gives X for points situated on the axis for which x is not less than $(b+c+f)$.

The expressions for forces which concern us now are those given by the general formulæ for $\frac{X}{\mu}$ and $\frac{Y}{\mu}$. And a moment's glance at these will show that they explain the apparent position of the pole at the very extremity of the coil: for, in order to ascertain the values of the forces in a plane at right angles to the axis passing through the extremity of the coil, we must make $\alpha=90^\circ$, $\sin\alpha=1$, $\cos\alpha=0$; and if the other end of the coil be very distant, β may be taken $=0$, $\sin\beta=0$, $\cos\beta=1$. Substituting these values, it will be seen at once that X, the longitudinal force, $=0$, while Y, the transversal force, has a value, which indicates a force directed to the extremity of the coil.

In order to make a complete comparison, I have, for all the eighteen stations treated in the former Tables, taken the values of α, β, and p graphically. For b I have adopted 0·45, and for $b+c$ 0·7; these numbers correspond to the internal and external surfaces of the coil, but they appear to me best to represent (though doubtless with some inaccuracy) the quantities used in the theoretical investigation. Then I have (with the kind assistance of EDWIN DUNKIN, Esq., of the Royal Observatory) made the complete calculation of the formulæ for every station. As the numbers first obtained were not immediately comparable, I have made them more nearly so by trebling the numbers given by theory and doubling those in the preceding Table. The results are as follows:—

Longitudinal ordinate.	Transversal ordinate, or p.	α.	β.	Result of theoretical calculation.		Theoretical result trebled.		Experimental result doubled.	
				X.	Y.	X.	Y.	X.	Y.
0·0	2·26	161° 10′	18° 40′	− 160	0	− 480	0	− 432	0
1·34	2·26	157 15	15 40	− 168	+ 30	− 504	+ 90	− 480	+ 76
2·68	2·26	151 0	13 25	− 208	+ 82	− 624	+ 246	− 630	+ 240
4·02	2·26	140 20	11 35	− 297	+206	− 891	+ 618	− 900	+ 650
5·36	2·26	121 55	10 15	− 354	+503	−1062	+1509	−1100	+1696
6·7	2·26	91 0	9 20	− 38	+855	− 114	+2565	− 160	+2960
7·78	1·70	58 25	6 10	+ 543	+771	+1629	+2313	+2020	+3260
8·2	0·74	28 0	2 35	+1417	+688	+4251	+2064	+4960	+2340
0·0	3·73	151 0	29 0	− 124	0	− 372	0	− 368	0
1·34	3·73	145 30	24 42	− 128	+ 32	− 384	+ 96	− 378	+ 82
2·68	3·73	137 20	21 30	− 139	+ 77	− 417	+ 231	− 400	+ 208
4·02	3·73	126 10	18 57	− 150	+148	− 450	+ 444	− 434	+ 424
5·36	3·73	110 5	16 58	− 109	+243	− 327	+ 729	− 246	+ 766
6·7	3·73	91 0	15 27	− 20	+295	− 60	+ 885	− 114	+ 848
7·83	3·44	73 0	13 2	+ 80	+308	+ 240	+ 924	+ 200	+ 872
8·82	2·8	54 5	10 0	+ 179	+281	+ 537	+ 843	+ 528	+ 820
9·49	1·82	34 35	6 10	+ 318	+223	+ 954	+ 669	+ 950	+ 676
9·7	0·73	14 25	2 5	+ 456	+120	+1368	+ 360	+1336	+ 372

In spite of some discordances in the large forces (which it was impossible to measure with accuracy), there is enough of agreement to show that confidence may be placed in the method of theoretically computing the attraction of the galvanic coil.

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